GROUND-WATER RESOURCES OF THE ALABAMA RIVER BASIN IN ALABAMA—*SUBAREA 8* OF THE APALACHICOLA-CHATTAHOOCHEE-FLINT AND ALABAMA-COOSA-TALLAPOOSA RIVER BASINS

By Robert E. Kidd, J.B. Atkins, and John C. Scott

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CONVERSION FACTORS

Multiply	by	to obtain
	Length	
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
square foot (ft^2)	0.0929	square meter
mile (mi)	1.609	kilometer
feet per mile (ft/mi)	0.1894	meter per kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.59	square kilometer
	Volumetric rate and volume	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	448.831	gallon per minute
	0.6463	million gallons per day
cubic foot per second per square mile ($ft^3/s/mi^2$)	0.01093	cubic meter per second per square kilometer
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second
	2.228×10^{-3}	cubic foot per second
	0.06308	liter per second
	1,440	gallon per day
gallon per day (gal/d)	3.785×10^{-3}	cubic meters per day
million gallons per day (Mgal/d)	1.547	cubic foot per second
	63.09	cubic meter per second
	694.44	gallons per minute
gallon per minute per foot of drawdown (gal/min/ft)	1.24×10^{-2}	cubic meters per minute per minute per meter of drawdown
acre-foot	325,900	gallon
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day

Temperature

Temperature in degrees Fahrenheit (° F) can be converted to degrees Celsius as follows:

$$° C = 5/9 \times (° F - 32)$$

ABBREVIATIONS AND ACRONYMS

7Q2	7-day, 2-year low flow
ACF	Apalachicola-Chattahoochee-Flint River basin
ACT	Alabama-Coosa-Tallapoosa River basin
Corps	U.S. Army Corps of Engineers
MOA	Memorandum of Agreement
GWSI	Ground Water Site Inventory database
MOVE.1	Maintenance of Variance Extension, Type 1; computer program (Hirsch, 1982)
RORA	Computer program (Rutledge, 1993)
SWGW	Surface Water-Ground Water; a computer program (Mayer and Jones, 1996)
USGS	U.S. Geological Survey

VERTICAL DATUM

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NVGD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

GLOSSARY

7Q2—Minimum average stream discharge for 7 consecutive days for a 2-year recurrence interval.

Alluvium—Sediment transported and deposited by flowing water.

Altitude—As used in this report, refers to the distance above sea level.

Anisotropic—Condition having varying hydraulic properties of an aquifer according to flow direction.

Annual—As used in this report, refers to a water year.

Aquifer—A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian—Synonymous with confined.

Baseflow—That part of the stream discharge that is not attributable to direct runoff from precipitation or melting snow; it is usually sustained by ground-water discharge.

Bedrock—A general term for the consolidated rock that underlies soils or other unconsolidated surficial material.

Clastics—Rocks composed of fragments of older rocks, for example, sandstone.

Colluvium—Heterogeneous aggregates of rock detritus resulting from the transporting action of gravity.

Cone of depression—A depression of the potentiometric surface, often in the shape of an inverted cone, that develops around a well which is being pumped.

Confined aquifer—An aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; ground water in the aquifer is under pressure significantly greater than that of the atmosphere.

Continuous-record gaging station—Complete records of discharge obtained using a continuous stage-recording device through which either instantaneous or mean-daily discharge may be computed for any time, or any period of time, during the period of record.

Crystalline rock—A general term for igneous and metamorphic rocks.

Darcian flow—Flow that is laminar and in which inertia can be neglected.

Dendritic drainage—A branching stream pattern that resembles the branching of trees.

Drought—There is no accepted definition of drought. As used in this report, a period of deficient rainfall extending long enough to cause streamflow to fall to unusually low levels for the period of record.

Evapotranspiration—The combined evaporation of water from the soil surface and transpiration from plants.

Faults—Fractures in the Earth along which there has been displacement parallel to the fault plane.

Foliation—A planar or layered structure in metamorphic rocks that is caused by parallel orientation of minerals or bands of minerals.

Fluvial—Pertaining to the actions of rivers.

Fracture—Breaks in rocks due to intense folding or faulting.

Geologic contact—The boundary surface between one body of rock or sediment and another.

Ground-water recharge—The process of water addition to the saturated zone or the volume of water added by this process.

Head, static—The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the elevation head and pressure head.

Head, total—The total head of a liquid at a given point is the sum of three components:
(a) the elevation head, which is equal to the elevation of the point above a datum, (b) the pressure head, which is the height of a column of static water that can be supported by the static pressure at the point, and (c) the velocity head, which is the height to which the kinetic energy of the liquid is capable of lifting the liquid.

Heterogeneous—Pertaining to a substance having different characteristics in differing locations.

Hydraulic conductivity—The capacity of a rock to transmit water. It is expressed as the volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Hydraulic gradient—A change in the static pressure of ground water, expressed in terms of the height of water above a datum, per unit of distance in a given direction.

Hydrograph separation—Division of the stream hydrograph into components of aquifer discharge and surface runoff.

Igneous rock—Rocks which have solidified or crystallized from a hot fluid mass called magma.

Intergranular porosity—Porosity resulting from space between grains.

Intrusive igneous rocks—Masses of igneous rock formed by magma cooling beneath the surface.

Isotropic—Condition in which hydraulic properties of an aquifer are equal in all directions.

Joints—Fractures in rocks, often across bedding planes, along which little or no movement has taken place.

Mafic—Applied to the ferromagnesian minerals or to igneous rocks relatively rich in such minerals.

Mean annual—As used in this report, refers to the average of the annual values for a specified period of record.

Metamorphic rock—Rocks derived from pre-existing rocks by mineralogical, chemical, and structural alterations due to endogenetic processes.

Partial-record gaging station—Is a particular site where limited streamflow and/or water-quality data are collected systematically over a period of years.

Permeability—The property of a porous medium to transmit fluids under an hydraulic gradient.

Porosity—The amount of pore space and fracture openings, expressed as the ratio of the volume of pores and openings to the volume of rock.

Potentiometric surface—An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a tightly cased well.

Primary porosity—Porosity due to the soil or rock matrix; the original interstices created when a rock was formed.

Recession index—The number of days required for discharge to decline one complete log cycle.

Regolith—Loose, unconsolidated and weathered rock and soil covering bedrock.

Residuum—The material resulting from the decomposition of rocks in place and consisting of the nearly insoluble material left after all the more readily soluble constituents of the rocks have been removed.

Rock—Any naturally formed consolidated material consisting of two or more minerals.

Run-off—Precipitation that flows from the surface of the land and into streams and rivers.

Saprolite—Surficial deposits produced by the decay of rocks and remaining as residuals.

Secondary openings—Voids produced in rocks subsequent to their formation through processes such as solution, weathering, or movement.

Secondary porosity—Porosity due to such phenomena as dissolution or structurally controlled fracturing.

Soil—The layer of unconsolidated material at the land surface that supports plant growth.

Specific capacity—The rate of discharge of water from the well divided by the related drawdown of the water level within the well.

Specific yield—The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium.

Storage coefficient—The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (virtually equal to the specific yield in an unconfined aquifer).

Stream discharge—The volume of water flowing past a given point in a stream channel in a given period of time.

Transmissivity—The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It equals the hydraulic conductivity multiplied by the aquifer thickness.

Trellis drainage—A river system resembling a trellis or rectangular pattern and characteristic of areas of folded sedimentary rocks where tributaries cut channels through less resistant beds.

Unconfined aquifer—An aquifer in which the water table is a free surface at atmospheric pressure.

Unit-area discharge—Stream or ground-water discharge divided by the drainage area.

Water table—Upper surface of a zone of saturation under atmospheric pressure.

Water year—The standard water-year used by the U.S. Geological Survey is from October 1 to September 30 of the second calendar year.

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ABSTRACT

Drought conditions in the 1980's focused attention on the multiple uses of the surface- and ground-water resources in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins in Georgia, Alabama, and Florida. State and Federal agencies also have proposed projects that would require additional water resources and revise operating practices within the river basins. The existing and proposed water projects create conflicting demands for water by the States and emphasize the problem of water-resource allocation. This study was initiated to describe ground-water availability in the Alabama River basin of Alabama, Subarea 8 of the ACF and ACT River basins, and to estimate the possible effects of increased ground-water use within the basin.

Subarea 8 encompasses about 6,750 square miles in the Coastal Plain physiographic province in central and southwestern Alabama. The Alabama River extends from the juncture of the Coosa and Tallapoosa Rivers near the city of Montgomery, to its juncture with the Tombigbee River, near the town of Calvert in Washington County. Subarea 8 includes the Cahaba River basin from the physiographic "Fall Line" at the city of Centreville in Bibb County, to its mouth in Dallas County; and the Alabama River basin from near Montgomery to the Alabama River cutoff, about 6 miles northeast of its juncture with the Tombigbee River.

The study area is underlain by sedimentary deposits of Cretaceous, Tertiary, and Quaternary ages. Major aquifers underlying Subarea 8 are, from shallowest to deepest, the Coastal lowlands aquifer system, the Floridan aquifer system, the Lisbon aquifer, the Nanafalia-Clayton aquifer, the Ripley aquifer, the Eutaw aquifer, and the Tuscaloosa aquifer.

The conceptual model described for this study qualitatively subdivides the ground-water flow system into local (shallow), intermediate, and regional (deep) flow regimes. Ground-water discharge to tributaries mainly is from local and intermediate flow regimes and varies seasonally. The regional flow regime probably approximates steady-state conditions and discharges chiefly to major drains such as the Alabama River, and in upstream areas, to the Cahaba River. Ground-water discharge to major drains originates from all flow regimes. Mean-annual ground-water discharge to streams (baseflow) is considered to approximate the long-term, average recharge to ground water. The mean-annual baseflow was estimated using an automated hydrograph-separation method, and represents discharge from the local, intermediate, and regional flow regimes of the ground-water flow system. Mean-annual baseflow discharging from Subarea 8 was estimated to be 20,300 cubic feet per second. Mean-annual baseflow represented about 61 percent of total mean-annual stream discharge for the period of record.

Estimated and measured stream discharge for selected sites on the Alabama River and its tributaries were compiled for the years 1941, 1954, and 1986, during which sustained droughts occurred throughout most of the ACF-ACT area. Stream discharges were assumed to be sustained entirely by baseflow during the latter periods of these droughts. Estimated baseflow near the end of the individual drought years was about 17 percent of the estimated mean-annual baseflow at the Alabama River cutoff, the most downstream point of Subarea 8.

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 8. Estimated ground-water use in 1990 was less than 1 percent of the estimated mean-annual baseflow, and about 2.4 percent of baseflow during the droughts of 1941, 1954, and 1986. Because ground-water use in Subareas 5 and 6 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subareas 5 and 6 in Georgia probably would have little effect on the quantity of ground water and surface water in Alabama. In addition, ground-water use in Subarea 3 in Georgia probably has no effect on the quantity of ground water and surface water in the Alabama River basin (Subarea 8) because of the lack of hydraulic connection between Subareas 3 and 8; similarly, ground-water use in Subarea 8 in Alabama probably has no effect on the quantity of ground water and surface water in Subarea 3. Although on a regional scale, only a small percentage of the mean-annual baseflow is utilized, large long-term withdrawals of ground water have resulted in the formation of local depressions in the potentiometric surfaces of some of the aquifers near pumping centers. Extensive depressions have formed in the Tuscaloosa aquifer near Montgomery, Prattville, Elmore, and Selma. Depressions in the potentiometric surface of the Eutaw aquifer have formed near Montgomery and Selma. A depression has formed in the potentiometric surface of the Nanafalia-Clayton aquifer in the Monroeville area.

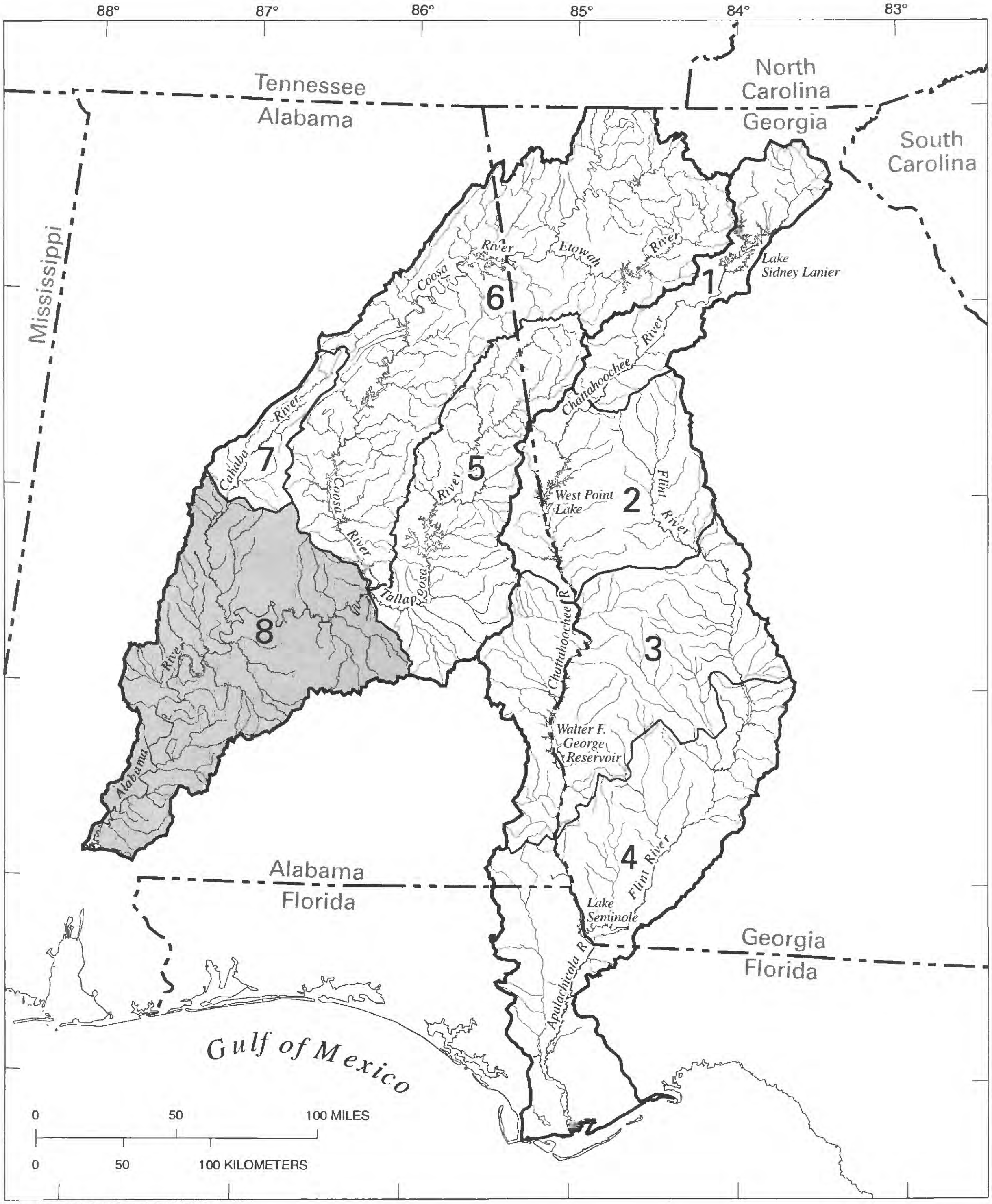
INTRODUCTION

Increased and competing demands for water and the droughts of 1980-81, 1986, and 1988 in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins have focused the attention of water managers and users in Alabama, Florida, and Georgia, on the water resources in the two basins. The ACF-ACT River basins encompass about 42,400 square miles (mi^2) and extend from near the Georgia-Tennessee State line, through most of central and southern Alabama and Georgia and part of the Florida panhandle to the Gulf of Mexico (fig. 1). Ground- and surface-water systems of the ACF-ACT River basins behave as an integrated, dynamic flow system comprised of an interconnected network of aquifers, streams, reservoirs, control structures, floodplains, and estuaries. The degree of hydrologic interaction between ground water and surface water suggests that the water resources be investigated and managed as a single hydrologic entity, to account for the climatic and anthropogenic factors that influence the flow systems.

Recent water projects and resource allocations, and other actions proposed by Federal, State, and local agencies, have resulted in conflicts among the States of Alabama, Florida, and Georgia, and the U.S. Army Corps of Engineers (Corps). The Corps has been given the authority to regulate the Nation's surface waters through the Rivers and Harbors Act of 1927, in accordance with the U.S. House of Representatives Document Number 308, 69th U.S. Congress. Proposed projects designed to increase development and to re-allocate surface-water supplies in Georgia, based on revised operating practices of control structures for flood control, navigation, and hydropower generation, and a proposal to construct a dam and reservoir have met with opposition from Alabama and Florida. As a result, in 1991, the U.S. Congress authorized the Corps to initiate a Comprehensive Study of the ACF-ACT River basins that would "develop the needed basin and water-resources data and recommend an interstate mechanism for resolving issues" (Draft Plan of Study, Comprehensive Study, Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River basins, prepared by: The Comprehensive Study Technical Coordination Group, July 1991, U.S. Army Corps of Engineers, Mobile District).

In 1992, the Governors of Alabama, Florida, and Georgia; and the U.S. Army, Assistant Secretary for Civil Works, signed a Memorandum of Agreement (MOA) establishing a partnership to address interstate water-resource issues and promote coordinated systemwide management of water resources. An important part of this process is the Comprehensive Study of the ACF and ACT River basins. Since this signing, the Study Partners defined scopes of work to develop relevant technical information, strategies, and plans, and to recommend a formal coordination mechanism for the long-term, basinwide management and use of water resources needed to meet environmental, public health, and economic needs (U.S. Army Corps of Engineers, written commun., 1993). The U.S. Geological Survey (USGS) was requested to assist in the development of a scope of work for the ground-water-supply element of the Comprehensive Study, and in June 1993, was asked to conduct that study element.

Eight subareas of the ACF-ACT River basins were identified by the Study Partners and the USGS on the basis of hydrologic and physiographic boundaries. Addressing the study at the smaller, subarea scale within the ACF-ACT River basins facilitated evaluation of the ground-water resources on a more detailed scale. This report is one of a series of eight reports that present results of ground-water studies of the ACF-ACT subareas.



Base from 1:100,000 and 1:250,000
USGS Digital Line Graph

Figure 1. Subareas and major streams in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Purpose and Scope

This report describes the ground-water resources of the Alabama River basin of Alabama—Subarea 8 of the ACF-ACT River basins. The report provides an analysis of ground-water resources that can be used to address resource-allocation alternatives created by existing and proposed uses of the water resources in the river basins. Specific objectives of this study were to:

- describe a conceptual model of ground-water flow and stream-aquifer relations;
- describe the hydrologic setting of Subarea 8;
- quantify mean-annual and drought period ground-water contributions to the Alabama River from its headwaters at the confluence of the Coosa and Tallapoosa Rivers near Montgomery, Ala., to the Alabama River cutoff about 6 miles (mi) northeast of its juncture with the Tombigbee River near the town of Calvert in Washington County and including the Cahaba River basin from the city of Centreville in Bibb County to the mouth in Dallas County, and quantify ground water entering and exiting Subarea 8; and
- describe and evaluate ground-water utilization and general development potential.

Findings contained herein are but one component of a multidiscipline assessment of issues related to the basinwide utilization and management of water. This report is not intended to provide definitive answers regarding the acceptability of ground-water-resource utilization or the potential for additional resource development. Such answers are dependent on the synthesis of results from all components of the Comprehensive Study and on subsequent consideration by the Federal, State, and local water-resource managers responsible for decision making within the basin.

The report scope includes literature and data searches and an assessment of existing geologic data. A conceptual model that describes the hydrologic processes governing the ground- and surface-water flow was developed, and an evaluation of ground-water utilization was made by compiling and evaluating existing hydrologic, geologic, climatologic, and water-use data. Field data were not collected during this study.

Physical Setting of Study Area

The Subarea 8 study area encompasses about 6,750 mi^2 in the central and southwestern parts of Alabama (fig. 1). The Alabama River extends from the juncture of the Coosa and Tallapoosa Rivers near the city of Montgomery, to its juncture with the Tombigbee River near the town of Calvert in Washington County. The Alabama River basin (Subarea 8) for this report includes the Cahaba River basin from the physiographic "Fall Line" at the city of Centreville in Bibb County, to its mouth in Dallas County and the Alabama River from near Montgomery to the Alabama River cutoff, about 6 mi northeast of its juncture with the Tombigbee River. The Alabama River basin (Subarea 8) is bounded on the northeast by the Tallapoosa River basin (Subarea 5), and on the north by the Coosa River basin (Subarea 6) and the Cahaba River basin (Subarea 7) (fig. 1).

Physiography

Subarea 8 lies entirely in the Coastal Plain physiographic province (Sapp and Emplaincourt, 1975) (fig. 2). Land surface elevations range from 850 to 50 feet (ft) above sea level. Relief generally is less than 300 ft and decreases towards the coast.

The sedimentary rocks underlying the province dip gently southward at about 20 to 40 feet per mile (ft/mi), increasing to as much as 50 ft/mi near the coast. Outcropping resistant beds form cuestas or ridges that face northward and slope gently southward. The cuestas form a series of arcuate, hilly belts trending east to southeast.

Climate

Alabama is classified as temperate, becoming largely subtropical near the coast, having hot, humid summers and relatively mild winters (Barksdale and Moore, 1976). Severe cold weather is rare in Subarea 8 and freezing temperatures usually do not continue for more than 48 consecutive hours. January is the coldest month, and July is the warmest. Precipitation occurs almost entirely as rain. Summer rainfall is primarily from local thunderstorms moving inland from the Gulf of Mexico, and winter precipitation is primarily from continental air masses moving south from the midwestern part of the continent. The average annual rainfall for stations in the Coastal Plain in Alabama is about 55 inches per year (in/yr). The range in monthly mean rainfall for 1961-90 was from 2.9 inches in October to 6.5 inches in March (National Oceanographic and Atmospheric Administration, 1993).

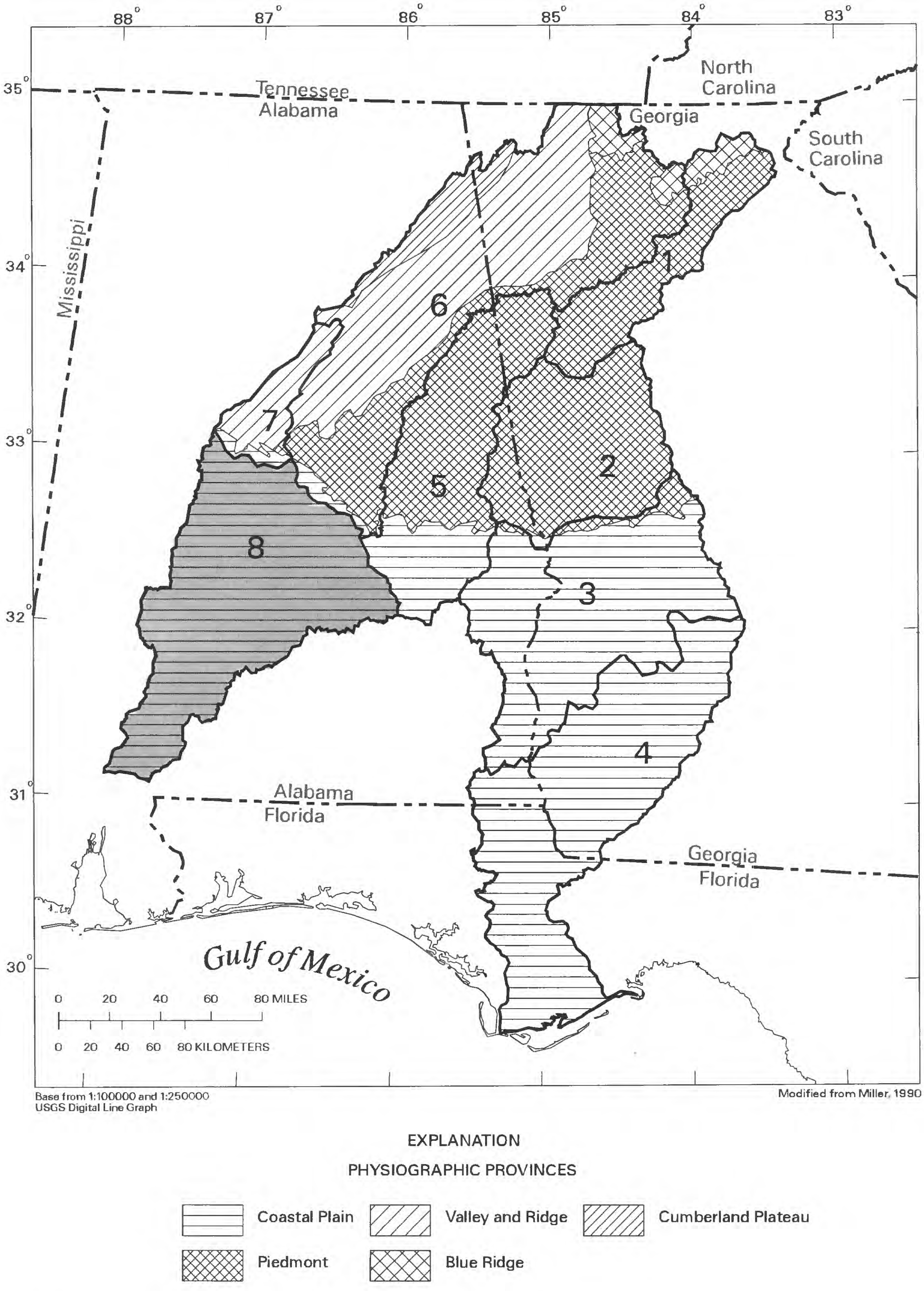


Figure 2. Physiographic provinces and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Ground-Water Use

The estimated ground-water use in Subarea 8 during 1990 was about 54 million gallons per day (Mgal/d) or about 83 cubic feet per second (ft^3/s) (Baker and Mooty, 1993). Of this total, about 65 percent was for public water supply, about 6 percent for domestic water supply, 9 percent was for self-supplied industrial and commercial activities, and 20 percent was for agricultural use. The largest ground-water use in Alabama is for public water supply (table 1).

Table 1. Estimated ground-water use, by category, Subarea 8, 1990
[Mgal/d, million gallons per day; ft^3/s, cubic feet per second]

	Public water supply		Self-supplied industrial and commercial		Agricultural		Domestic		Total	
	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)
Subarea 8 total	**34.6**	**53.5**	**4.9**	**7.6**	**11.0**	**17.0**	**3.3**	**5.1**	**53.8**	**83.2**

Ground-water use reported by Baker and Mooty (1993) is by county; ground-water use in those counties that are partially in Subarea 8 are reported herein for Subarea 8 only. Ground-water use for public water supply, and self-supplied industrial and commercial uses were determined by using site-specific data. Ground-water pumpage for domestic purposes was determined by subtracting the population served by public supply facilities from the total population of the county or hydrologic unit, then multiplying that number by a water-use coefficient of 75 gallons per day (gal/d) per person. Agricultural ground-water use was estimated by multiplying the reported county use by the percentage of the land area of the county in Subarea 8.

Previous Investigations

Many reports that include Subarea 8 have been published by the USGS and the Geological Survey of Alabama from as early as the beginning of the 1900's. These reports contain information on topics such as geology, water availability, descriptions of major aquifers, and water quality. An early study on the ground-water resources of Alabama includes a report by Smith (1907).

Water availability reports have been published for each county in the study area. These reports detailing data on geology and availability of water for the counties in the Alabama River basin were prepared by the USGS in cooperation with the Geological Survey of Alabama and include: Scott (1957, 1960, 1972); Ivey (1957); LaMoreaux and Toulmin (1959); Newton and others (1961); Cagle and Newton (1963); Knowles and others (1963a,b); Reed, Newton, and Scott (1967); Reed, Scott, Golden, and Avrett (1967); Causey and McCain (1971); Newton and others (1971); Causey and Newton (1972;, Scott and others (1972); Reed (1972); Reed and others (1972); Lines (1975); Causey and others (1978),; Ellard and Willmon (1980); Willmon (1980a,b,c); Scott and others (1981); and Chandler (1987).

Brief descriptions of local ground-water quality are also given in the reports listed above. The following reports describe ground-water quality in greater detail and are areally more extensive: Avrett (1968); Lee (1984, 1985, 1986, 1988a, 1988b); Miller (1986, 1992); Davis (1987); Moore and Hunter (1991); Moore and others (1991); and Mallory (1993).

Reports on Alabama streams by Peirce (1967), Hayes (1978), and Atkins and Pearman (1994) investigated 7 day low flows and flow durations. Baker and Mooty (1987, 1993) reported on the use of water in Alabama for the years 1985 and 1990. Faye and Mayer (1990) provided information on ground-water flow and stream-aquifer relations of the Coastal Plain. Reports describing major aquifers in Alabama, their recharge areas, and areas susceptible to contamination were prepared by the USGS in cooperation with the Alabama Department of Environmental Management. Cook (1993) reported on the Eutaw aquifer in Alabama and stated that "increased demands for good quality water have resulted in pumpage of water beyond the capacity for replenishment of the aquifer."

One of the earliest reports containing information on dry-weather flow of streams in Alabama was "Water Powers of Alabama" (Hall and Hall, 1916). Peirce (1955) described the hydrology and surface-water resources of the ACT River basin area in Alabama to the mouth of the Cahaba River. Wentz and others (1986a,b) described drought-related impacts on water uses in northern Alabama. Moore (1988) listed recent droughts in Alabama and described drought severity. Hale and others (1989) described the effects of the drought of 1986 on streamflow in Alabama, Georgia, North Carolina, South Carolina, Tennessee, and Virginia.

Reports describing methods of estimating streamflow and ground-water discharge to streamflow include Bingham (1982), Hirsch (1982), Hoos (1990), Rorabaugh (1960, 1964), Rutledge (1991, 1992, 1993), and Mayer and Jones (1996). Data collected as part of the ongoing surface-water monitoring program of the USGS are published annually in the reports "Water-Resources Data, Alabama." Other reports containing information about the surface- and ground-water resources of the ACF-ACT River basin area are listed in the "Selected References" section of this report.

Well and Surface-Water Station Numbering Systems

The well-numbering system in Alabama is based on the Federal system of subdivision of public lands into townships and ranges. Each township is divided into 36 sections numbered from one in the northeast corner to 36 in the southeast corner. Each township is assigned a letter in the same order that sections are numbered from "A" through "X," with "A" being assigned to the northeasternmost equal subdivision of the section and "X" to the southeasternmost subdivision. Letter designations are doubled or tripled as needed. Wells in each subdivision are numbered consecutively such as A-1, A-2. Wells in each county are often subsequently assigned a three-letter abbreviation corresponding to the county and a number corresponding to the well. For example, well K-07 in Montgomery County is also identified as MTG-3.

Wells in the USGS Ground-Water Site Inventory (GWSI) data base are assigned a 15-digit identification number based on the latitude and longitude grid system. The first six digits denote the degrees, minutes, and seconds of latitude. The next seven digits the degrees, minutes, and seconds of longitude. The last two digits (assigned sequentially) identify wells within a one-second grid.

The USGS established a standard identification numbering system for all surface-water stations in 1950. Stations are numbered according to downstream order. Stations on a tributary entering upstream of a main-stream station are numbered before and listed before the main-stream station. No distinction is made between continuous-record and partial-record stations. Gaps are left in the series of numbers to allow for new stations that may be established; hence, the numbers are not consecutive. The complete number for each station includes a two-digit part number "02" plus the downstream-order number, which can be from 6 to 12 digits. All records for a drainage basin, encompassing more than one State, can easily be correlated by part number and arranged in downstream order.

Approach and Methods of Study

This study included several work elements used to appraise the ground-water resources of Subarea 8, including the description of a conceptual model of ground-water flow and stream-aquifer relations, and an assessment of ground-water availability. The approach and methods used to accomplish these tasks included:

- compilation of information and data from pertinent literature, including geologic, ground-water, streamflow, and ground-water use data;
- separation of streamflow hydrographs to estimate the mean-annual ground-water contribution to the Alabama River and its tributaries;
- evaluation of streamflow records and periodic discharge measurements during drought periods to estimate "worst-case" streamflow conditions; and
- comparison of 1990 ground-water use with mean-annual and drought-flow conditions to evaluate ground-water availability.

Literature and data reviews provided information necessary to describe a conceptual model of ground-water/surface-water relations. Much of the conceptual model is based on results of previous investigations by Toth (1962, 1963), Freeze (1966), Freeze and Witherspoon (1966, 1967, 1968), Winter (1976), Faye and Mayer (1990), Heath (1984), and Miller (1990). These studies suggest that large rivers, such as the Alabama, and their tributaries function as hydraulic drains for ground-water flow, and that during significant droughts, most of the discharge in these streams is contributed by ground water.

Streamflow data were compiled from the USGS Automated Data Processing System (ADAPS) database. Streamflow records from continuous-record and miscellaneous discharge-measurement stations were used for hydrograph-separation analyses and drought streamflow evaluation.

Stream-aquifer relations were quantified using two approaches: (1) the hydrograph-separation method of Rorabaugh (1960, 1964) and Daniel (1976), called the recession-curve-displacement method; and (2) a drought-flow mass-balance analysis of streamflow. The hydrograph-separation method was used to estimate the mean-annual discharge of ground water (baseflow) to the basin. The mean-annual baseflow was used as a base or reference with which to compare and evaluate droughts under "worst-case" conditions. The mass-balance analysis was used to estimate drought baseflow contributions to the surface-water system during historically significant droughts and the ground water delivered as baseflow near the end of these droughts.

Mean-Annual Baseflow Analysis

Discharge data from continuous-record gaging stations along the Alabama River and its tributaries were selected for baseflow analysis based on the period of record of unregulated flow. Streamflow representative of low, average, and high years of stream discharge were evaluated by hydrograph-separation methods to estimate annual baseflow. The mean-annual baseflow was then computed as the average baseflow of the three representative flow years.

The selection process for the most representative year of low, average, and high stream discharge involved objective statistical examination of the discharge data, followed by some subjectivity in the final choice of the water year selected. Hydrographs acceptable for separation were characterized by relatively normal distributions of daily stream discharge, small ranges of discharge, and the absence of extremely high, isolated peak stream discharge. For each station, the mean annual stream discharge was computed for the period of record of unregulated flow and used as a reference mean for low-, average-, and high-flow conditions for that station. The mean- and median-annual stream discharge for those water years identified as acceptable were compared to the reference mean. Because extremely high discharge during a water year could greatly influence the mean but not the median (which is similar to the geometric mean for positively skewed data sets, such as discharge), the process of selecting representative water years for low-, average-, and high-flow conditions considered the position of the mean discharge for the selected year relative to the median and the reference mean. The hydrographs for these representative water years were examined and separated. True subjectivity in the selection process entered only at this point, such that, if acceptable hydrographs were available for several years, one year arbitrarily was chosen over the others.

The separation analyses were conducted using the computer program SWGW (Mayer and Jones, 1996) which is an automated version of the recession-curve-displacement method, often referred to as the Rorabaugh or Rorabaugh-Daniel method. The SWGW program was applied to a water-year period of streamflow data. SWGW utilizes daily mean discharge data collected at unregulated stream-gaging sites and requires at least 10 years of record to accurately estimate a recession index necessary for hydrograph-separation analysis.

The hydrograph-separation method estimates the ground-water component of total streamflow. In general, the streamflow hydrograph can be separated into two components—surface runoff and baseflow (ground-water discharge to streams). Figure 3 shows the graphical output from the SWGW program. Surface runoff is the quick response (peaks) of stream stage to precipitation and nearby overland flow.

Application of the recession-curve-displacement method requires the use of the streamflow recession index. The streamflow recession index is defined as the number of days required for baseflow to decline one order of magnitude (one log cycle), assuming no other additional recharge to the ground-water system. The streamflow recession index is a complex number that reflects the loss of ground water to evapotranspiration (Daniel, 1976) or leakage, and the influence of geologic heterogeneities in the basin (Horton, 1933; Riggs, 1963). The slope of the streamflow recession is affected by evapotranspiration, such that the streamflow recession index varies from a maximum during the major rise period to a minimum during the major recession period (fig. 3). The major rise period of streamflow generally occurs from November through March or April, when precipitation is greatest and evapotranspiration is least. The major recession period occurs during late spring through fall and coincides with a period of lesser precipitation, higher temperatures, and greater evapotranspiration (fig. 3). Two recession indices were estimated for streamflow observed at each continuous-record gaging station used in the mean-annual baseflow analysis; one index for the major rise period and one for the major recession period.

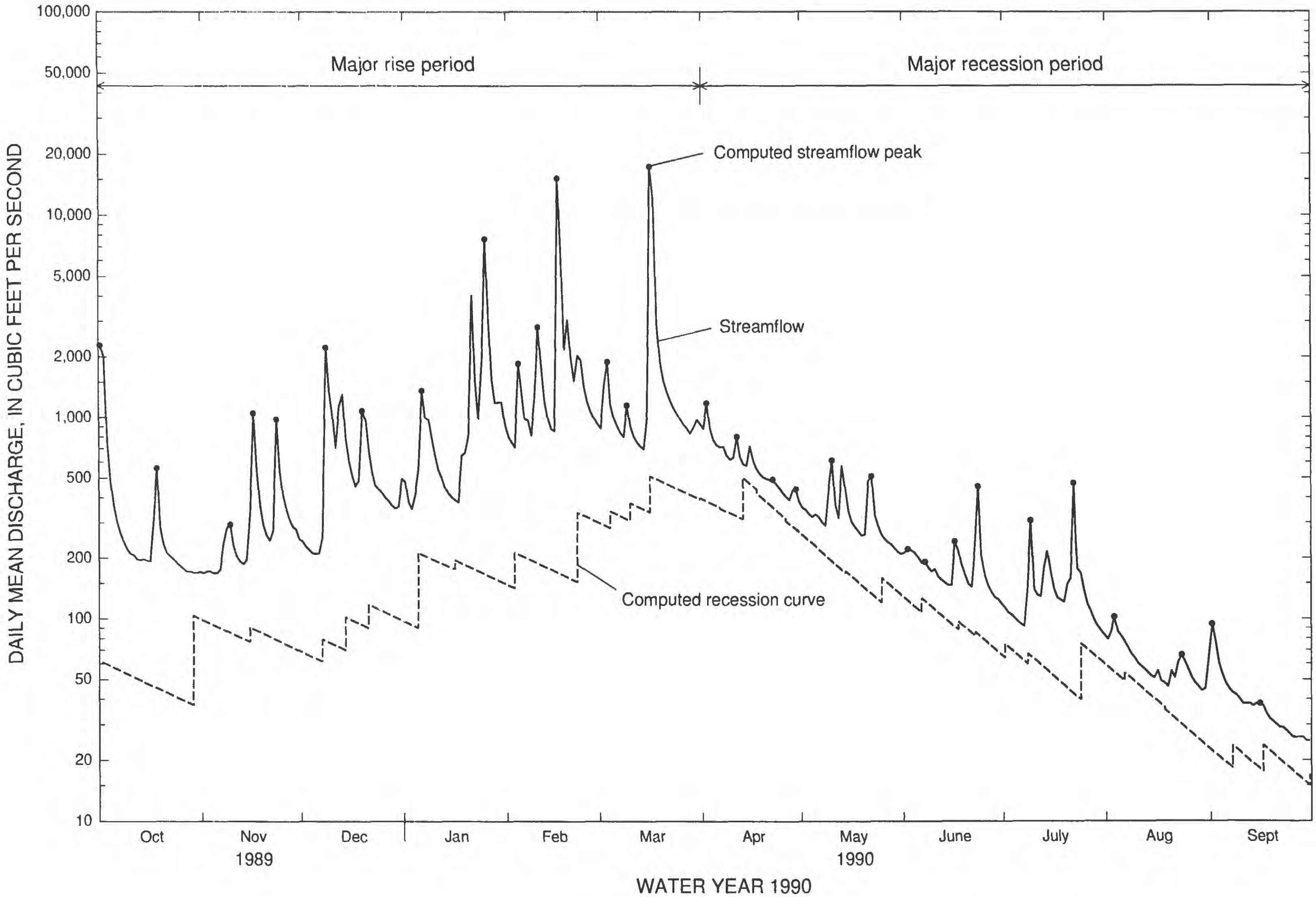


Figure 3. Streamflow hydrograph, separated by program SWGW.

Results of the mean-annual baseflow analysis are based on measured and estimated data, and the analytical methods to which they are applied. Drainage areas were measured using the most accurate maps available at the time of delineation (Novak, 1985), and are reported in units of square miles. Drainage areas are reported to the nearest square mile for areas greater than 100 mi^2; to the nearest tenth of a square mile for areas between 10 and 100 mi^2; and to the nearest hundredth of a square mile for areas less than 10 mi^2, if the maps and methods used justify this degree of accuracy (Novak, 1985). Annual stream discharge, the sum of the daily mean stream discharges for a given water year, is reported in units of cubic feet per second, to the nearest cubic foot per second. Daily mean discharge is reported to the nearest tenth of a cubic foot per second for discharge between 1.0 and 9.9 cubic foot per second (ft^3/s); to the nearest unit for discharge between 10 and 100 ft^3/s; and is reported using three significant figures for discharge equal to or greater than 100 ft^3/s (Novak, 1985).

The accuracy of stream-discharge records depends primarily on: (1) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements; and (2) the accuracy of measurements of stage and discharge, and the interpretation of records. Accuracy of records of streamflow data used in this report can be found in annually published USGS data reports, for example Pearman and others (1994). The accuracy attributed to the records is indicated under "REMARKS" in the annual data reports for each station. "Excellent" means that about 95 percent of the daily discharges are within 5 percent of the true discharge; "good," within 10 percent; and "fair," within 15 percent. Records that do not meet these criteria are rated "poor." The accuracy of streamflow records at a station may vary from year to year. In addition, different accuracies may be attributed to different parts of a given record during a single year (Novak, 1985).

Results of the mean-annual baseflow analyses are inherently uncertain. The hydrograph-separation method of analysis is partly subjective, relying on the input of several user-selected variables. As such, the results of the analyses derived and reported herein, are difficult to independently confirm and are presented as estimates of unknown quality and confidence. However, because the values in this report are used in several water budgets, not only within Subarea 8 but also from subarea to subarea, hydrograph separation results may be reported to a greater significance than the data and analyses warrant to maintain the numerical balance of the water budget; implication of accuracy to the extent shown is not intended.

Drought-Flow Analysis

Daily mean streamflow data collected at gaging stations during periods of low flow and corresponding periodic measurements of stream discharge collected at partial-record stations were compiled for the drought years 1941, 1954, and 1986. These data included nearly concurrent daily measurements of streamflow in the Alabama River and periodic measurements of tributary discharge.

Standard periods of analyses for drought studies were selected for all ACF-ACT subareas. The period of analysis selected for compiling 1954 drought data was September 15 through November 1, 1954. The selected period for the 1986 drought was July 1 through August 14, 1986. Streamflow during these periods was considered to represent the "worst case" of ground-water storage and availability throughout the ACF-ACT study area. Discharge data were sparse during the 1941 drought; therefore, a standard period of analysis was not selected for the entire ACF-ACT study area.

The period of "worst-case" conditions may not include the minimum streamflow that occurred during a drought at a streamflow measurement site. Minimum drought flows typically occur at different times at different stations within large watersheds, such as the Alabama River basin. Rather, the "worst-case" evaluation was designed to describe streamflow during the advanced stages of each drought; thus, providing a near-contemporaneous summary of streamflow conditions during periods of low flow throughout the ACF-ACT study area.

The estimated "worst-case" distribution of Alabama River streamflow during the 1941, 1954, and 1986 drought periods was determined by balancing mass in the stream network in a general downstream direction during a relatively short interval of time. The tributary discharge to the Alabama River during drought periods was calculated using a unit-area discharge extrapolated to the entire drainage area of the tributary. Unit-area discharges are based on streamflow measurements that generally are inclusive of only part of the tributary drainage, and may not be representative of an average unit-area discharge for the entire tributary drainage. Therefore, most unit-area discharges used to estimate discharge at ungaged and unmeasured tributaries were based on streamflow data measured near the mouths of tributaries to better represent the entire tributary contributing area.

Because daily discharge or periodic discharge measurements did not exist for some sites during all or some of the three drought periods, estimates of the daily discharge at those sites during the drought periods were based on correlation methods that use relations of available discharge data from other periods. The logarithms of these discharge data were correlated with the logarithms of concurrent daily discharges at selected continuous-record gaging stations (index stations). The relation was defined by a line of correlation determined by a technique known as MOVE.1—Maintenance of Variance Extension, Type 1 (Hirsch, 1982)—or by a graphically determined best-fit line (Riggs, 1972). The MOVE.1 technique was used instead of ordinary least-squares regression to develop these relations because it produces an estimate that is less biased than the ordinary least-squares regression.

Drought streamflow daily discharges were estimated for 1941, 1954, and 1986 for partial-record and continuous-record stations where at least 10 discharge measurements were available, using the MOVE.1 line and the concurrent daily discharge for the index station. This estimating technique transfers a selected daily discharge from the index station using the MOVE.1 line of correlation to determine the corresponding daily discharge for the partial-record station or continuous-record station (dependent station). This technique assumes that daily discharges will occur concurrently at the dependent station and the index station and that the two stations drain hydrologically and geologically similar basins in close geographical proximity. Partial-record stations having fewer than 10 discharge measurements, or where relations between dependent stations and index stations were not linear, were correlated with index stations by a graphical technique. A graphically determined best-fit line through an x-y plot of concurrent daily discharge for the index station and discharge data for the dependent station was used for estimating daily discharges (Riggs, 1972).

CONCEPTUAL MODEL OF GROUND-WATER FLOW AND STREAM-AQUIFER RELATIONS

The conceptual model of the hydrologic system in Subarea 8 is based on previous work done in other areas by Toth (1962, 1963), Freeze (1966), Freeze and Witherspoon (1966, 1967, 1968), Winter (1976), and Faye and Mayer (1990). These studies suggest that recharge originates from precipitation that infiltrates the land surface, chiefly in upland areas, and percolates directly, or leaks downward to the water table. Ground water subsequently flows through the aquifer down the hydraulic gradient and either discharges to a surface-water body or continues downgradient into confined parts of an aquifer. Major elements of this conceptual model include descriptions of flow regimes, stream-aquifer relations, recharge to ground water, and ground-water discharge to streams.

Toth (1963) observed that most ground-water flow systems could be qualitatively subdivided into paths of local (shallow), intermediate, and regional (deep) flow. Local flow regimes are characterized by relatively shallow and short flow paths that extend from a topographic high to an adjacent topographic low. Intermediate flow paths are longer and somewhat deeper than local flow paths and contain at least one local flow path. Regional flow paths (fig. 4) begin at or near the major topographic (drainage) divide and terminate at regional drains, which is the Alabama River in Subarea 8. Depending on local hydrogeologic conditions, all three flow regimes may not be present everywhere within the subarea.

The water table in Subarea 8 probably is a subdued replica of the land-surface topography but generally has less relief. The presence of ground-water flow regimes depends largely on the configuration of the water table, such that recharge occurs in highland areas and discharge occurs in lowland areas. Quantities of recharge to the water table and net ground-water discharge to streams are variably distributed throughout the local, intermediate, and regional flow regimes. Local regimes receive the greatest ground-water recharge from the water table and provide the most ground-water discharge to streams. Ground-water discharge to tributary drainages primarily is from local and intermediate flow regimes; ground-water discharge to regional drains, such as the Alabama River includes contributions from the regional as well as local and intermediate regimes.

Seasonal variation in rainfall affects the local ground-water flow regime most significantly, and affects the regional flow regime least significantly. Generally, regional flow probably approximates steady-state conditions, and long-term recharge to and discharge from this regime will not vary significantly.

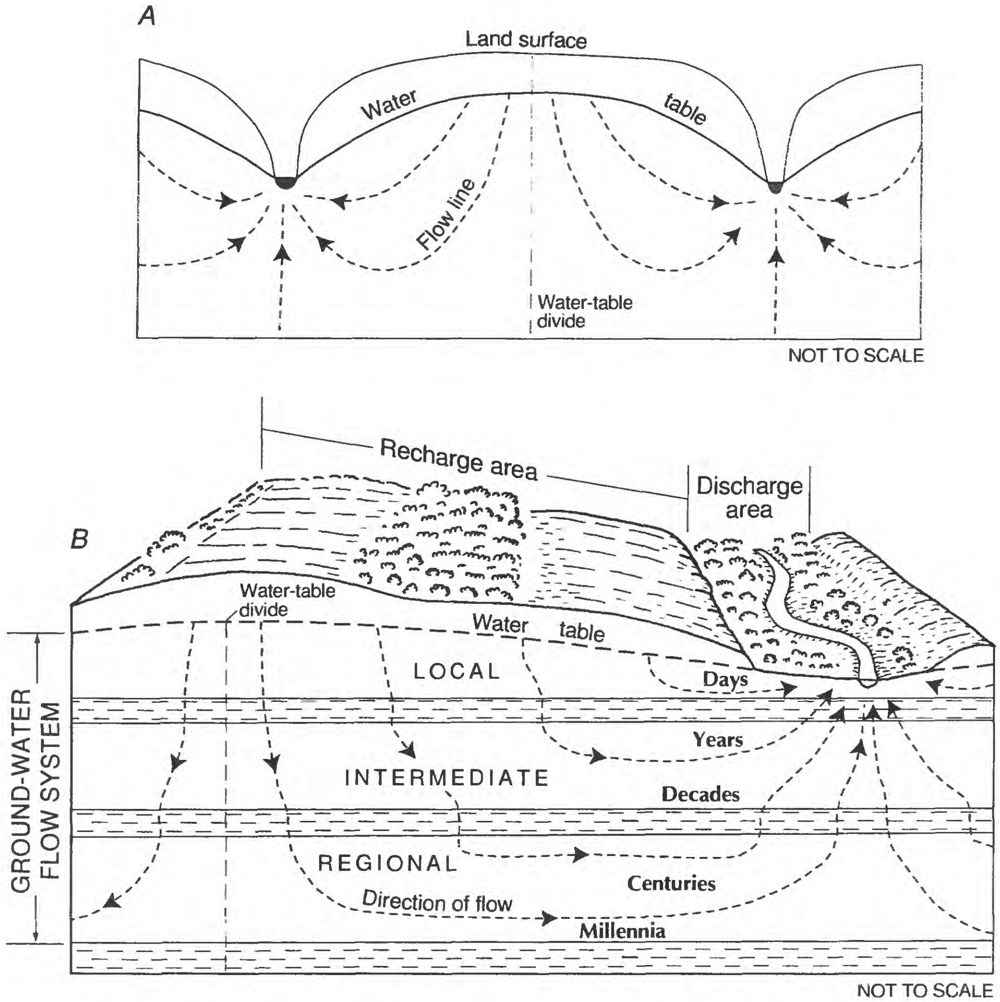


Figure 4. (*A*) Distribution of ground-water flow in an areally extensive, isotropic, homogeneous aquifer system (modified from Hubbert, 1940, and Heath, 1984) and (*B*) example of local, intermediate, and regional ground-water flow (modified from Heath, 1984).

HYDROLOGIC SETTING

The hydrologic framework of Subarea 8 contains dynamic hydrologic systems consisting of aquifers, streams, reservoirs, and floodplains. These systems are interconnected and form a single hydrologic entity that is stressed by natural hydrologic and climatic factors and by anthropogenic factors. For this discussion, the hydrologic framework is separated into two systems: the ground-water system and surface-water system.

Ground-Water System

The ground-water system forms as geology and climate interact. Geology primarily determines the aquifer types present, as well as the natural quality and quantity of ground water. Climate primarily influences the quantity of ground water.

Geology

The Coastal Plain deposits in Alabama form a thick wedge of unconsolidated to poorly consolidated clastic and carbonate rocks that dip generally south to southwestward from the Fall Line (inner margin of the Coastal Plain) toward the Gulf of Mexico at about 20 to 40 ft/mi, increasing to as much as 50 ft/mi near the coast (Davis, 1987). The deposits range in thickness from a featheredge at the Fall Line to as much as an estimated 21,000 ft near the coast. They are underlain in places by metamorphic and igneous rocks of Precambrian and Paleozoic age and in other places by sedimentary rocks of Paleozoic and early Mesozoic age. The rocks underlying the Coastal Plain sediments are, in part, a southern and southwestern extension of the Piedmont Province and, in part, a southwestern extension of the Valley and Ridge Province. These rocks of Precambrian to early Mesozoic age, combined, constitute the pre-Cretaceous Coastal Plain floor or base of the aquifer system as used in this report. A detailed description of the diverse and complex geology of Subarea 8 is beyond the scope of this study. Descriptions of geologic formations underlying the basin may be found in Scott (1957), LaMoreaux and Toulmin (1959), Knowles and others (1963a,b), Reed (1972), Scott and others (1981), Miller (1990), and Cook (1993).

Coastal Plain sediments of Subarea 8 are parts of three regional aquifer systems: Southeastern Coastal Plain aquifer system, Floridan aquifer system, and Coastal lowlands aquifer system (fig. 5). The principal part of the Southeastern Coastal Plain aquifer system in Subarea 8 consists of clastic deposits of Early and Late Cretaceous, Paleocene, and early and middle Eocene age. The Floridan aquifer system consists of calcareous deposits of Oligocene and Eocene age. The Coastal lowlands aquifer system is an off-lapping sequence of fluvial, deltaic, and marine deposits of Miocene age and younger (Martin and Whiteman, 1989).

Hydrogeology

Aquifers in Subarea 8 (fig. 5) vary in their lithologic and water-bearing characteristics (table 2). Two types of aquifers are present in the Subarea, identified on the basis of their ability to store and yield water: (1) porous-media; and (2) solution-conduit aquifers (table 2). These aquifer types differ fundamentally in origin and water-supply potential.

Porous-media aquifers (fig. 6) typically consist of unconsolidated or poorly consolidated sediments. In these aquifers, ground water moves through interconnected pore spaces between sediment grains. The space between sediment grains is termed voids or interstices, and the interconnection of these spaces allows water to flow through the sediments. Such flow is said to be the result of primary permeability. The porous-media aquifers occur in sand and gravel deposits in the alluvial plain of the Alabama River and in clastic deposits in the southeastern Coastal Plain (figs. 1 and 2).

Solution-conduit aquifers of Subarea 8 (Floridan aquifer system) occur in sandy carbonate rocks in a small band in Clarke and Monroe Counties. The study of the occurrence and development of ground water in solution-conduit aquifers is an area of specialization and is only briefly explained here. The carbonate rocks of Subarea 8 have little primary porosity or permeability. Secondary porosity features, such as solution-enlarged fractures and bedding planes, form a system of interconnected conduits through which water moves (Scott and others, 1972). The carbonate-rock aquifers are anisotropic and heterogeneous because of the local and discontinuous nature of water-bearing units in the bedrock.

Wells completed in the Floridan aquifer system in Subarea 8 generally supply less than 50 gallons of water per minute. Wells that do not intercept secondary porosity zones will, however, seldom supply more than 10 gallons per minute (gal/min) or may be dry. As in any solution-conduit aquifer system, ground-water withdrawal and consequent water-level declines could induce sinkhole development. The likelihood of sinkhole development would depend on several factors—including, but not limited to—quantity of water withdrawn, amount of water-level decline, proximity of solution conduits to the land surface, and land-surface loading.

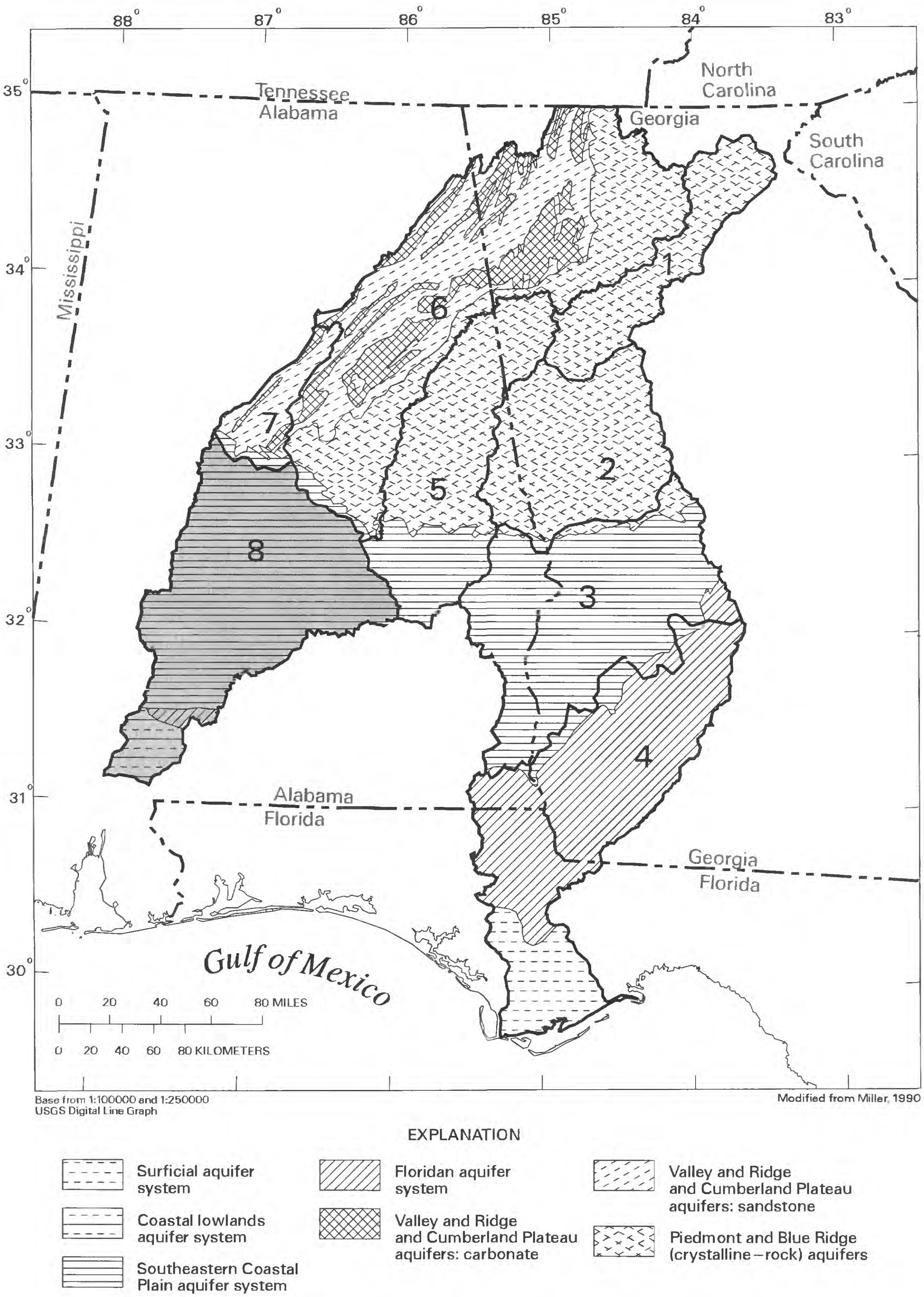


Figure 5. Major aquifers and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

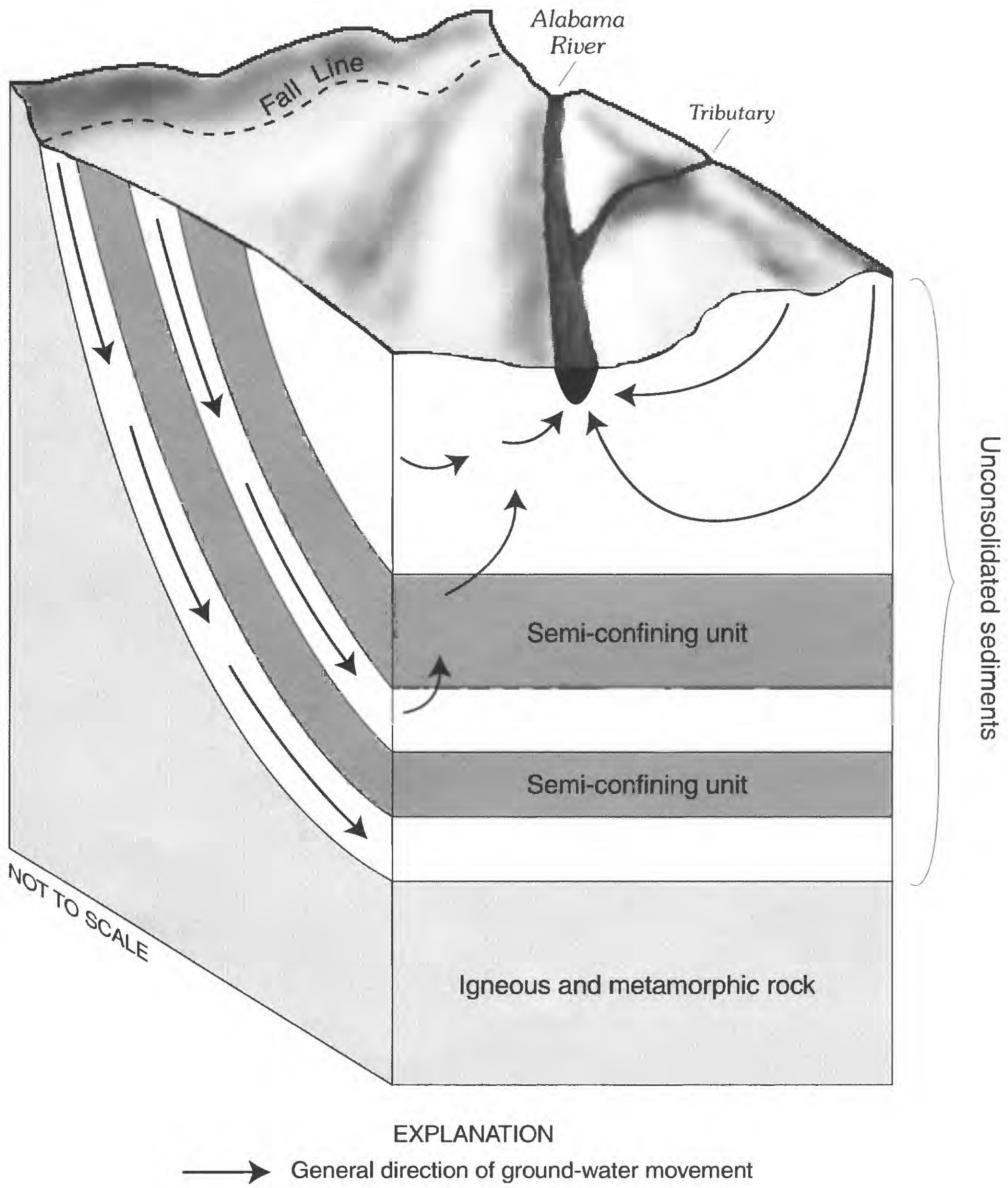


Figure 6. Conceptual ground-water and surface-water systems in Subarea 8: porous-media aquifer in unconsolidated sediments of the Coastal Plain Province.

Table 2. Generalized hydrogeologic units in Subarea 8, and water-bearing properties, chemical characteristics, and well yields

Physiographic province	Geologic age and lithology	Hydrogeologic unit and type	Water-bearing properties and chemical characteristics	Well yield
Coastal Plain	Pliocene and Miocene—sands, gravels, clays of the Pliocene age Citronelle Formation and undifferentiated deposits of Miocene age	Coastal lowlands aquifer system; porous-media	used for public water supply in Monroe and Escambia Counties. Water soft. Locally may contain high concentrations of iron and may be corrosive	100 to 500 gallons per minute (Davis, 1987)
Coastal Plain	Oligocene and Eocene—limestone, sandy clay of the Oligocene age Vicksburg Group and the Eocene age Ocala Limestone	Floridan aquifer system; solution-conduit	source of domestic supply. Water soft to very hard. Locally may contain high concentrations of iron	generally less than 50 gallons per minute
Coastal Plain	Eocene—limestone, marl, and sandy clay of the Yazoo Clay and Moodys Branch Formation	Yazoo confining unit	no available data	no available data
Coastal Plain	Eocene—sand, gravel, clays of the Lisbon, Tallahatta, and Hatchetigbee Formations and the upper part of the Tuscahoma Sand	Lisbon aquifer; porous-media	extensive domestic supply source in Clarke and Monroe Counties. Water is soft to very hard. Locally may contain high concentrations of iron	generally less than 100 gallons per minute (DeJarnette, 1989)
Coastal Plain	Eocene—clay of the lower part of the Tuscahoma Sand	Tuscahoma confining unit	no available data	no available data
Coastal Plain	Paleocene—sand in lower part of Tuscahoma Sand, sand, clay, and gravelly-sand in Nanafalia Formation	Nanafalia-Clayton aquifer; porous-media	public supply source in Monroe and Clarke Counties. Water is generally soft. Locally hard and may contain high concentrations of iron	75-900 gallons per minute (Barksdale and Moore, 1976)
Coastal Plain	Paleocene—chalky marl, limestone and clay of the Porters Creek Formation and the Clayton Formation	Prairie Bluff confining unit	no available data	no available data
Coastal Plain	Upper Cretaceous—chalk and clay of the Prairie Bluff Chalk	Prairie Bluff confining unit	no available data	no available data
Coastal Plain	Upper Cretaceous—calcareous sandstone, sandy chalk, clay of the Ripley Formation	Ripley aquifer; porous-media	public supply in Lowndes and Wilcox Counties. Water is soft to moderately hard. Locally, may contain high concentrations of iron	75-200 gallons per minute (Barksdale and Moore, 1976)
Coastal Plain	Upper Cretaceous—chalk of the Demopolis Chalk and Mooreville Chalk	Selma confining unit	no available data	no available data
Coastal Plain	Upper Cretaceous—sand and gravel of the Eutaw Formation	Eutaw aquifer; porous-media	extensive use as public supply in northern and central parts of basin. Soft to moderately hard water. Locally, may contain high concentrations of chloride and iron	up to 700 gallons per minute (Scott and others, 1987)
Coastal Plain	Upper Cretaceous—clay of the upper part of the Gordo Formation	Gordo confining unit	no available data	no available data
Coastal Plain	Upper Cretaceous—sand and gravel of the Gordo and Coker Formations	Tuscaloosa aquifer; porous-media	major source of public water supply in northern and central parts of the basin. Soft to hard water. Locally, may contain high concentrations of iron	200 to 500 gallons per minute (Scott and others, 1987)

The Southeastern Coastal Plain aquifer system is subdivided into five major aquifers. The aquifers are, from shallowest to deepest, the Lisbon aquifer, the Nanafalia-Clayton aquifer, the Ripley aquifer, the Eutaw aquifer, and the Tuscaloosa aquifer (table 2). The recharge areas for the aquifers generally coincide with their areas of outcrop. The recharge areas for the Coastal lowlands and Floridan aquifer systems generally coincide with their outcrop areas in northern Baldwin and Escambia Counties, southeastern Clarke County, and southern Monroe County. The recharge area for the Lisbon aquifer extends across northeastern Clarke County and northern and central Monroe County. The recharge area for the Nanafalia-Clayton aquifer extends across southeastern Marengo County, southern Wilcox County, and northeastern Monroe County. The recharge area for the Ripley aquifer extends across central Marengo County, southern Dallas County, and southeastern Lowndes County. The recharge area for the Eutaw aquifer extends across northern Perry and Dallas Counties and central and southern Autauga County. The recharge area for the Tuscaloosa aquifer extends across southern Bibb and Chilton Counties, northern Autauga County, and western Elmore County.

The Coastal lowlands aquifer system consists of sand and gravelly sand beds in the Citronelle Formation of Pliocene age and sand beds in the undifferentiated Miocene Series. These formations crop out in southern Clarke and Monroe Counties, northwestern Escambia County, and northern Baldwin County. The maximum thickness of the Citronelle Formation in the basin is about 50 ft. The maximum thickness of the Miocene Series is about 300 ft. Consequently, the principal aquifer consists of sand beds in the Miocene Series.

Public water-supply wells in the Alabama River basin that are developed in the Coastal lowlands aquifer system are all screened in Miocene sand beds. The towns of Excel, Frisco City, Megargel, and Uriah in Monroe County, and Huxford in Escambia County obtain water supplies from the aquifer. Well production ranges from 100 to 380 gal/min, and specific capacities, the rate of discharge of water from the well per unit of drawdown, range from 10 to 23 gallons per minute per foot (gal/min/ft). The aquifer is a source of domestic water supplies over extensive areas of Clarke and Monroe Counties.

The Floridan aquifer system consists of limestone of Eocene and Oligocene age. Areas of outcrop occur in central and southern Clarke County and southern Monroe County. The maximum thickness of the Floridan aquifer system in the Alabama River basin is about 375 ft.

Well yields from the Floridan aquifer system are relatively small in Subarea 8. The Ocala Limestone is a part of the high-yielding Floridan aquifer system in southeastern Alabama. However, the Ocala grades westward into the Yazoo Clay which is a confining unit. The city of Monroeville in Monroe County used the Floridan aquifer system for water supply until the 1950's. Well production from the Floridan at Monroeville ranged from 75 to 175 gal/min. Test drilling in the Floridan aquifer system in 1991-92 in eastern Clarke County and southwestern Monroe County indicates that the aquifer system generally will yield less than 50 gal/min per well (Don Mills, Goodwin, Mills and Cawood, oral commun., Jan. 11, 1994). The Floridan aquifer system is a source of domestic water supplies in southern Clarke and Monroe Counties.

The Floridan aquifer system in the Alabama River basin is separated from the underlying Lisbon aquifer by the Moodys Branch Formation and the Yazoo Clay (Ivey, 1957). The Moodys Branch Formation and the Yazoo Clay, which are the chronostratigraphic equivalent of the Ocala Limestone in southeastern Alabama, form a confining unit between the Floridan aquifer system and the underlying Lisbon aquifer. The Yazoo Clay is 50 ft or more thick in Subarea 8.

The Lisbon aquifer consists of sand beds in the Lisbon, Tallahatta, and Hatchetigbee Formations, and the upper part of the Tuscahoma Sand. These formations crop out across the central and northern parts of Clarke and Monroe Counties, and dip beneath the Floridan aquifer system. The combined thickness of these formations generally ranges from 200 ft in the northeastern part of Monroe County to 600 ft in southern Clarke County.

Well yields from the Lisbon aquifer are relatively small in the Alabama River basin. The city of Monroeville developed water from the Lisbon until the 1950's. Production from these wells ranged from 75 to 140 gal/min. Test drilling in the Lisbon aquifer in 1991-92 in eastern Clarke and southwestern Monroe Counties indicates that the aquifer generally will yield less than 100 gal/min (Don Mills, Goodwin, Mills and Cawood, oral commun., 1994). The aquifer is a source of domestic water supplies over extensive areas of Clarke and Monroe Counties.

The Nanafalia-Clayton aquifer in the Alabama River basin consists of sand beds in the lower part of the Tuscahoma Sand and sand- and gravelly-sand beds in the Nanafalia Formation. Farther east in Alabama, the aquifer includes permeable limestone beds in the Clayton and Porters Creek Formations, but these formations are not sufficiently permeable in the Alabama basin to yield useful quantities of water to wells. Areas of outcrop of the Tuscahoma Sand and the Nanafalia Formation occur across northwestern Butler County, southern and central Wilcox County, and southeastern Marengo County. Clay beds in the Tuscahoma Sand function as a confining unit between the Nanafalia-Clayton aquifer and the overlying Lisbon aquifer. The combined thickness of the lower part of the Tuscahoma Sand and the Nanafalia Formation is more than 300 ft. The thickness of permeable beds that compose the aquifer is about 150 ft.

The Nanafalia-Clayton aquifer is the source of public-water supply for Beatrice and Monroeville and the Monroe County water system in Monroe County, and for Thomasville in northeastern Clarke County. Available data indicate that water in the Nanafalia-Clayton aquifer is highly mineralized south and southwest of Monroeville, and is not suitable for public or domestic use. Wells developed in the Nanafalia-Clayton aquifer produce 75 gal/min at Beatrice, as much as 275 gal/min at Thomasville, and as much as 900 gal/min at Monroeville. Estimates from capacity tests in wells at Monroeville indicate that the transmissivity of the aquifer is about 2,000 ft^2/d in the Monroeville area.

The Providence-Ripley aquifer in the Alabama River basin is limited to sand beds in the Ripley Formation. The Providence Sand is part of the aquifer in southeastern Alabama, but is thin and relatively impermeable in southwestern Montgomery County, and is absent west of Lowndes County. Therefore, in this report, the aquifer is referred to as the Ripley aquifer. The Ripley Formation crops out across southern Dallas, Lowndes, and Montgomery Counties, northwestern Wilcox County, and central Marengo County. Principal sand beds that compose the aquifer are in the lower part of the Ripley Formation, and generally are 100 to 150 ft thick.

The Ripley aquifer is separated from the overlying Nanafalia-Clayton aquifer by relatively impermeable limestone and clay in the Clayton Formation, chalk of the Prairie Bluff Chalk, and clay, siltstone, and silty limestone that occur within the upper part of the Ripley Formation. As much as 1,000 ft of chalk and calcareous clay in the Demopolis and Mooreville Chalks separate the Ripley aquifer from the underlying Eutaw aquifer.

Public-water systems in the Alabama River basin that tap the Ripley aquifer for water supply are the city of Fort Deposit in Lowndes County (wells are in Conecuh River basin), Camden and Pineapple in Wilcox County, and the Wilcox County rural water system (table 1). The Fort Deposit wells produce about 300 gal/min. Wells in Wilcox County produce from 75 to 200 gal/min. The Ripley Formation becomes thin and relatively impermeable west of the Alabama River, and is not a major source of water supply west of Wilcox County.

The Eutaw aquifer consists of sand beds in the Eutaw Formation. The Eutaw Formation crops out across northern Montgomery County, large areas of Autauga County, and northern Dallas and Perry Counties. Throughout most of the Alabama River basin, the Eutaw aquifer consists of two sand zones—the upper zone is equivalent to the Tombigbee Sand Member of the Eutaw Formation (Stephenson, 1914), and the lower zone is equivalent to the McShan Formation of western Alabama (Monroe). The thickness of the Eutaw Formation generally ranges from 250 to 400 ft. The upper and lower zones that constitute the Eutaw aquifer range in total thickness from 100 to 200 ft.

The Eutaw aquifer is separated from the overlying Ripley aquifer by the Mooreville and Demopolis Chalks. The maximum thickness of these formations is about 1,000 ft. The Eutaw aquifer is separated from the underlying Tuscaloosa aquifer by a clay zone in the upper part of the Gordo Formation of the Tuscaloosa Group. The thickness of the clay zone ranges from less than 20 ft near the city of Montgomery to more than 100 ft in southern Dallas County.

The Eutaw aquifer is extensively developed in conjunction with the underlying Tuscaloosa aquifer by the city of Montgomery Waterworks. The aquifer is the source of water supply for several rural water systems as well, including the town of Ramer in central and southern Montgomery County. The city of Selma develops part of its water supply from the Eutaw aquifer. The town of Orrville in Dallas County uses the Eutaw aquifer as do rural water systems in southern Dallas County. The city of Marion in Perry County obtains part of its water supply from the Eutaw aquifer, as does the town of Uniontown.

Aquifer tests indicate that the transmissivity of the Eutaw aquifer ranges from about 1,870 to 3,750 feet squared per day (ft^2/d) (Knowles and others, 1963a,b) in southwestern Montgomery County, most of Lowndes County, southeastern Dallas County, the southeastern part of Marengo County, and all of Wilcox County except the northwestern part.

The Tuscaloosa aquifer consists of sand beds in the Gordo and Coker Formations of the Tuscaloosa Group. These formations crop out across southern Elmore County, northern Autauga County, southern Chilton and Bibb Counties, and northern Perry County. The Gordo Formation ranges in thickness from about 100 ft at outcrops to more than 400 ft in the subsurface in Dallas, Marengo, and Wilcox Counties. The Coker Formation ranges in thickness from about 300 ft at outcrops to more than 1,000 ft in the subsurface. The Tuscaloosa aquifer is composed of massive coarse-grained sand in the lower part of the Gordo Formation, marine sand beds in the upper and middle parts of the Coker Formation and, in some areas, sand and gravelly-sand beds in the basal part of the Coker Formation. The total thickness of the Tuscaloosa aquifer generally ranges from 100 ft at outcrops to more than 300 ft in some areas in the subsurface.

The Tuscaloosa aquifer is a major source of water supply for the cities of Montgomery, Selma, and Marion, and is the sole source of supply for the city of Millbrook in Elmore County, the cities of Prattville, Billingsley, and Autaugaville in Autauga County, Maplesville in Chilton County, and rural water systems in Autauga, Chilton, Dallas, and Elmore Counties.

Aquifer tests in the Tuscaloosa aquifer at Montgomery indicate that the transmissivity of the Tuscaloosa aquifer is about 1,200 ft^2/d. Capacity tests in the Tuscaloosa aquifer at Selma indicate that the transmissivity of the aquifer in Dallas County may be as much as 4,800 ft^2/d. The Tuscaloosa aquifer is the most widely-used aquifer in Subarea 8, and is the most productive.

Ground-Water Levels

Ground-water levels fluctuate in response to natural and anthropogenic processes, such as seasonal changes in rainfall, interaction with the surface-water system, and ground-water withdrawal. These fluctuations indicate changes in the amount of water in storage in an aquifer. In Subarea 8, long-term water-level data were available for 1 well in the Coastal lowlands aquifer system for the period 1985-93; 1 well in the Lisbon aquifer for the period 1967-93; 30 wells in the Nanafalia-Clayton aquifer for the period 1967-93; 20 wells in the Ripley aquifer for the period 1952-93; 90 wells in the Eutaw aquifer for the period 1952-93; and 1 well in the Tuscaloosa aquifer for the period 1963-93.

Ground-water levels in wells in Subarea 8 ranged from 37.40 to 87.46 ft below land surface in the Coastal lowland aquifer system; from 180.51 to 217.54 ft in the Lisbon aquifer; from 46.70 to 402.10 ft in the Nanafalia-Clayton aquifer; from 1.17 to 254.70 ft in the Ripley aquifer; from 0.00 to 335.55 ft in the Eutaw aquifer; and from 87.41 to 97.26 ft in the Tuscaloosa aquifer.

The hydrograph of well MTG-3 (fig. 7) completed in the Eutaw aquifer in Montgomery County, Ala., shows water-level fluctuations that probably are typical of many wells in Subarea 8. Annual low water levels occur in the fall after the dry summer; and annual high water levels occur in the early spring because of recharge following rainfall during the winter. Although the water level fluctuates seasonally, significant year-to-year or long-term change in the average water level in the aquifer has not occurred. This suggests that mean-annual recharge and discharge are approximately equal, and during the period 1952 to 1993, permanent changes in storage in the aquifer probably have not occurred.

The hydrograph of well T-10 completed in the Ripley aquifer in Wilcox County (fig. 7) shows a decline in water level due to nearby pumping. The long-term change in the average water level in the aquifer suggests that mean-annual discharge exceeded recharge during 1967 to 1987.

Large long-term withdrawals of ground water have resulted in the formation of local depressions in the potentiometric surfaces of some of the aquifers near pumping centers in Subarea 8. An extensive depression covering about 1,600 mi^2 has formed near Montgomery, Prattville, Elmore, and Selma (Williams, DeJarnette, and Planert, 1986a; Scott and others, 1987; Mooty, 1987). Depressions in the potentiometric surface of the Eutaw aquifer have formed near Montgomery and Selma; each of these depressions covers about 50 mi^2. A depression covering about 10 mi^2 has formed in the Nanafalia-Clayton aquifer in the Monroeville area (Castleberry and others, 1989).

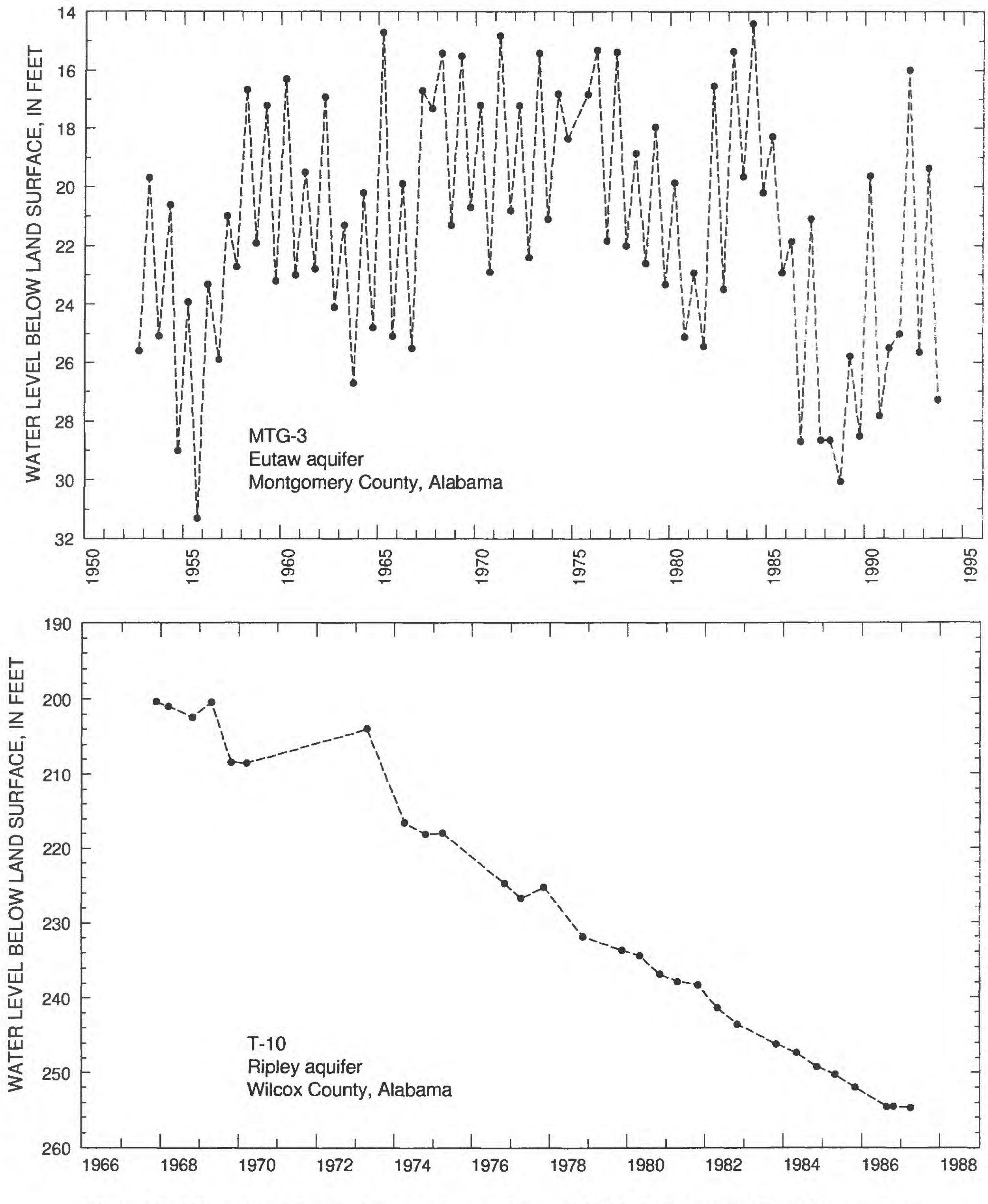


Figure 7. Water-level fluctuations in observation well MTG-3, Eutaw aquifer, Montgomery County, Alabama, 1952-93; and in observation well T-10, Ripley aquifer, Wilcox County, Alabama, 1967-87. Locations of wells shown in Figure 8.

The significance of whether or not an aquifer in the area of a pumping center reaches equilibrium (recharge equals discharge) is that, if equilibrium is attained, the current pumping rate for the center may be considered dependable. However, if water levels continue to decline, a condition could ultimately occur when additional withdrawal from the aquifer at the current rate would be impossible.

Surface-Water System

The surface-water system in Subarea 8 includes the Alabama River and its tributaries. The drainage area of the Alabama River basin encompasses about 6,750 mi^2 in Alabama (U.S. Army Corps of Engineers, 1985a,b). The confluence of the Coosa and Tallapoosa Rivers near the city of Montgomery, Ala., forms the Alabama River. The drainage area of the Alabama River at the confluence of the Coosa and Tallapoosa Rivers is 14,836 mi^2 (U.S. Army Corps of Engineers, 1985a,b). From the confluence near Montgomery, the Alabama River flows west to southwest to the Alabama River cutoff about 6 mi northeast of its juncture with the Tombigbee River near the town of Calvert in Washington County. The Alabama River basin for this report includes the Cahaba River basin from the "Fall Line" at the city of Centreville in Bibb County, to its mouth in Dallas County (fig. 8). The other major tributaries of the Alabama River drain from the north and west include Mortar, Autauga, Swift, Mulberry, Boguechitto, Chilatchee, and Turkey Creeks; major tributaries draining from the south and east are Catoma, Pintlalla, Big Swamp, Cedar, Pine Barren, Pursley, Big Flat, and Limestone Creeks, and Little River.

For this report, the mean-annual stream discharge of a surface-water drainage measured at a gaging station is defined as the arithmetic average of all reported annual discharges for the period of record. Note that, by definition, the stream discharge includes both surface runoff and baseflow.

The estimated mean-annual contribution of stream discharge of the Alabama River at the confluence of the Coosa and Tallapoosa Rivers (Subareas 5 and 6—Subarea 8 boundary) is about 21,500 ft^3/s, using values based on data for one continuous-record streamflow-gaging station—Alabama River near Montgomery, Ala. (0242000) (table 3; fig. 8). The mean-annual stream discharge entering Subarea 8 from Subarea 7 at the Cahaba River at Centreville is about 1,600 ft^3/s. The estimated mean-annual stream discharge of the Alabama River at the cutoff to the Tombigbee River (exiting Subarea 8) is about 32,500 ft^3/s (table 3); this value, which is representative of essentially the entire Alabama River basin, is based on data for the continuous-record streamflow-gaging station—Alabama River at Claiborne, Ala. (02429500).

The Cahaba River downstream of Centreville and all southward-flowing tributaries east of the Cahaba River drain the recharge areas of the Eutaw and Tuscaloosa aquifers. These streams are characterized by relatively high (dry weather) baseflows, reflecting the magnitude of recharge to and storage within these aquifers.

Catoma, Pintlalla, and Big Swamp Creeks, which flow northward through Montgomery and Lowndes Counties, drain mainly the Demopolis and Mooreville Chalks, which are relatively impermeable. Consequently, baseflow in these streams is relatively low and streamflow is zero during the latter parts of droughts and prolonged dry periods. Boguechitto Creek drains mainly the Demopolis and Mooreville Chalks in Dallas and Perry Counties, but its headwaters are in the recharge area of the Eutaw aquifer. The small baseflow in this stream may be attributed to discharge from the Eutaw aquifer or from the extensive alluvial deposits overlying the chalk in Dallas County. Turkey Creek drains the Naheola and Porters Creek Formations, which are relatively impermeable, and also drains the recharge area of the Nanafalia-Clayton aquifer in Marengo and western Wilcox Counties. The baseflow in Turkey Creek is attributed to discharge from the Nanafalia-Clayton aquifer.

Cedar and Pine Barren Creeks drain recharge areas of the Nanafalia-Clayton and Ripley aquifers, but are characterized by relatively low baseflows because large parts of the drainage basins are composed of poorly permeable sediments. Big Flat Creek flows southwestward to the Alabama River west of the city of Monroeville and drains the recharge area of the Lisbon aquifer, which also is composed of poorly permeable sediments.

Limestone Creek flows westward through Monroe County to the Alabama River near Claiborne Lock and Dam. The stream drains recharge areas of the Floridan aquifer system and Lisbon aquifer, and the baseflow of the stream is much higher than baseflow in Big Flat Creek. For example, the median 7-day low flow of Big Flat Creek near Fountain is 0.028 cubic feet per second per square mile [$(ft^3/s)/mi^2$]; the median 7-day low flow of Limestone Creek near Monroeville is 0.198 $(ft^3/s)/mi^2$. The higher base flow in Limestone Creek is attributed to the relatively greater permeability of the Floridan aquifer system recharge area.

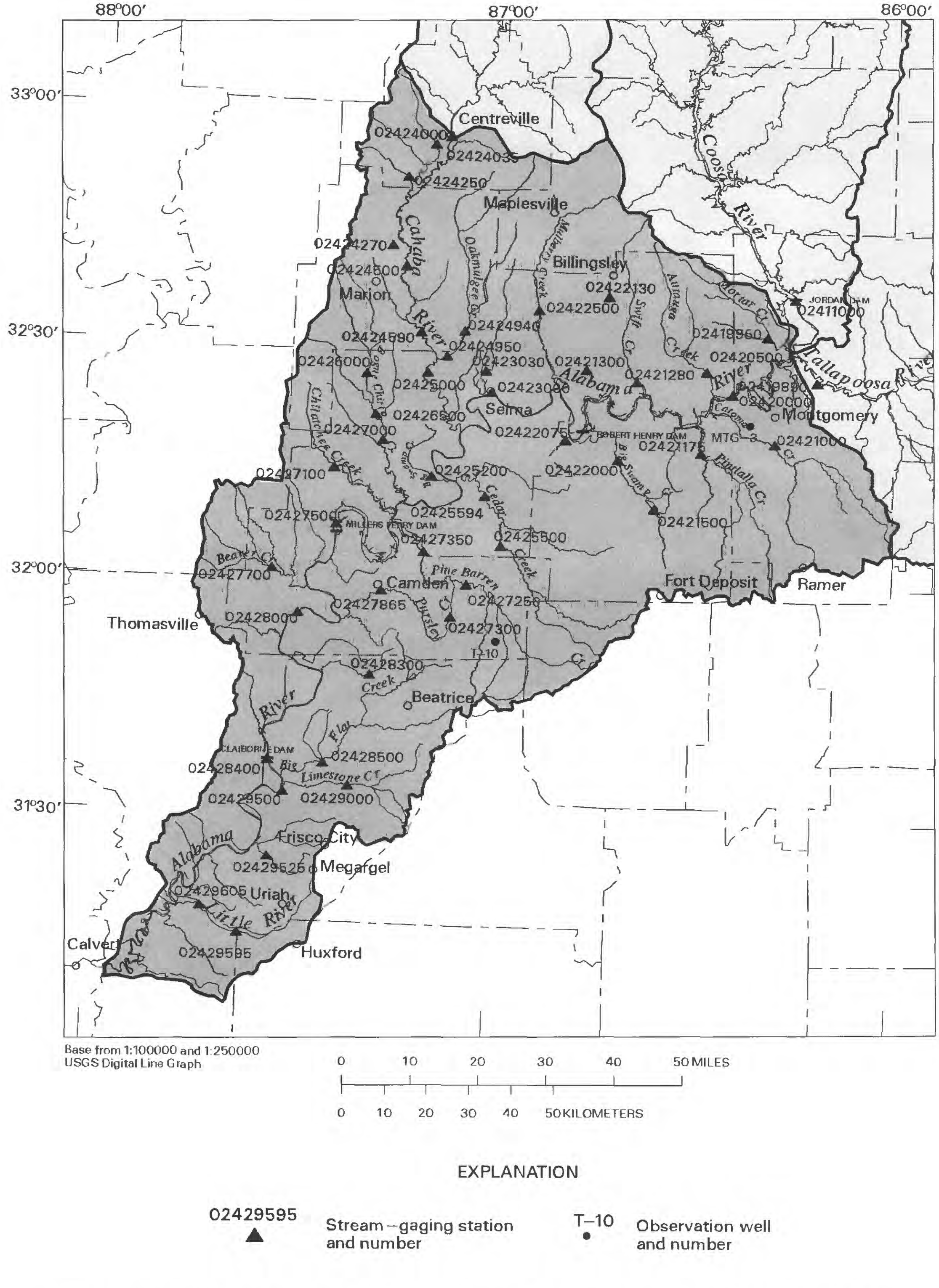


Figure 8. Selected stream-gaging stations and observation wells T-10 and MTG-3, Subarea 8.

Table 3. Selected active and discontinued continuous-record stream-gaging stations in the Alabama River basin, Subarea 8

[S, solution-conduit aquifer; P, porous-media aquifer; —, not applicable]

Station number	Station name	Drainage area (square miles)	Type of stream	Major aquifer drained	Period of record of unregulated flow	Mean-annual stream discharge (cubic feet per second)
02420000	Alabama River near Montgomery, Ala.	15,087	regional	P	—	[1/]23,890
02420500	Autauga Creek at Prattville, Ala.	116	tributary	P	1939-59	[2/]185
02421000	Catoma Creek near Montgomery, Ala.	290	do.	P	1952-71, 1974-93	[1/]367
02422000	Big Swamp Creek near Lowndesboro, Ala.	244	do.	P	1940-71	[2/]294
02422500	Mulberry Creek at Jones, Ala.	203	do.	P	1938-70, 1974-93	[1/]315
02423000	Alabama River at Selma, Ala.	17,095	regional	P	1900-13	[2/]26,170
02424000	Cahaba River at Centreville, Ala.	1,027	do.	P	1901-08, 1929-32, 1935-93	[1/]1,598
02424500	Cahaba River at Sprott, Ala.	1,370	do.	P	1938-69	[2/]2,002
02424940	Oakmulgee Creek near Augustin, Ala.	220	tributary	P	1975-87	[2/]303
02425000	Cahaba River near Marion Junction, Ala.	1,766	regional	P	1938-54, 1968-93	[1/]2,840
02425200	Big Swamp Creek near Orrville, Ala.	35.8	tributary	P	1972-85	[2/]50
02425500	Cedar Creek at Minter, Ala.	211	do.	P	1952-70, 1974-82	[2/]250
02426000	Boguechitto Creek near Browns, Ala.	95.4	do.	P	1944-54, 1965-71	[2/]129
02427500	Alabama River near Millers Ferry, Ala.	20,600	regional	P	—	[2/]30.330
02427700	Turkey Creek at Kimbrough, Ala.	97.5	tributary	P	1958-93	[1/]136
02428400	Alabama River at Claiborne Lock and Dam near Monroeville, Ala.	21,473	regional	P	—	[1/]33.560
02428500	Big Flat Creek near Fountain, Ala.	247	tributary	P	1943-70	[2/]284
02429000	Limestone Creek near Monroeville, Ala.	121	do.	S, P	1952-70	[2/]148
02429500	Alabama River at Claiborne, Ala.	21,967	regional	P	—	[2/]32,540
02429595	Little River near Uriah, Ala.	95.2	tributary	P	1968-79	[2/]183

[1/]Pearman and others (1994).

[2/]Atkins and Pearman (1994).

The Little River flows westward to the Alabama River along the southern boundary of Monroe County. The river drains the recharge area of the Coastal lowlands aquifer system in southern Monroe County, northwestern Escambia County, and northernmost Baldwin County. The baseflow of this stream is the highest of any tributary of the Alabama River. The median 7-day low flow of Little River near the town of Uriah is 0.646 $(ft^3/s)/mi^2$.

The Alabama River basin contains three major impoundments (fig. 8; table 4). The impoundments mainly are used for power generation, navigation, and recreation. The first was completed in 1969 near Claiborne, Ala., and the last in 1971 near Camden, Ala. Total reservoir storage in the Alabama River basin is 662,360 acre-feet.

Table 4. Major impoundments in the Alabama River basin, Subarea 8

Impoundment structure	Station number	Location	Installation date	Major uses	Total storage capacity[1/] (acre-feet)
Robert F. Henry Lock and Dam	02421351	Lowndes County, Ala.	1971	power generation, navigation, recreation	234,200
Millers Ferry Lock and Dam	02427506	Wilcox County, Ala.	1970	do.	331,800
Claiborne Lock and Dam	02428401	Monroe County, Ala.	1969	navigation	96,360

[1/]Ruddy and Hitt (1990).

The floodplains of the Alabama and Cahaba Rivers extend as much as 5 mi from the river channels at some places, and terraces (remnants of older floodplains) extend several miles beyond the floodplains. The floodplains and terraces are underlain by alluvial sediments that generally are very permeable. Where the alluvial deposits overlie subcrops of major aquifers, they are a major source of recharge to the aquifers. Where the deposits overlie chalk or clay, they are a potential source of ground water and baseflow to streams.

GROUND-WATER DISCHARGE TO STREAMS

Streamflow is comprised of two major components—a typical hydrograph integrates these components as:

- overland or surface runoff, represented by peaks, indicating rapid response to precipitation; and
- baseflow, represented by the slope of the streamflow recession, indicating ground-water discharge to the stream.

In relation to the conceptual model, baseflow in streams is comprised of contributions from the local, intermediate, or regional ground-water flow regimes. Estimates of recharge to the ground-water system are minimum estimates because the budgets were developed as ground-water discharge to streams, and do not include ground water discharged as evapotranspiration, to wells, or ground water that flows downgradient into other aquifers beyond the topographic boundary defining Subarea 8. Local flow regimes likely are the most affected by droughts. Discharge measured in unregulated streams and rivers near the end of a drought should be relatively steady and composed largely of baseflow.

Mean-Annual Baseflow

Mean-annual baseflow was determined by estimating mean-annual ground-water discharge to the Alabama River and its major tributaries. Streamflow data used to determine mean-annual ground-water discharge at continuous-record gaging stations were selected according to periods of record when flow was unregulated. The hydrograph-separation program SWGW (Mayer and Jones, 1996) was applied to estimate mean-annual baseflow at 15 continuous-record gaging stations in the Alabama River basin (table 5) including 2 stations on the Alabama River and 3 stations on the Cahaba River. For each gaging station, two recession indices are listed in table 5; one represents the rate of streamflow recession during the major rise period, generally in winter, and the other during the major recession period, generally in summer. Some variables that are supplied by the user to SWGW for each hydrograph separation are not listed in table 5, but can be obtained from the U.S. Geological Survey, Alabama District Office, Montgomery, Ala. These variables include the time base (in days) from the peak to the cessation of surface runoff, the time period (the beginning and ending months) for application of the summer recession index, and the adjustment factor for the displacement of the recession curve. See Rutledge (1993) for a discussion of time base, and Mayer and Jones (1996) for a discussion of the other user-supplied variables.

Because the only unregulated period of record for the Alabama River was available at the Selma gage (station 02423000) during the 1900 through 1913 water years, daily stream discharges were synthesized for the Alabama River at Claiborne gage (station 02429500) by use of a MOVE.1 relation. The modified hydrograph-separation method SWGW was applied to the synthesized daily stream discharge record to obtain an estimate of the ground-water discharge near the mouth of the Alabama River.

The mean-annual baseflow, in cubic feet per second; and the related unit-area baseflow, in cubic feet per second per square mile, were computed for each station. Unit-area mean-annual baseflow estimated for one station representing discharge from a solution-conduit aquifer was 0.818 $ft^3/s/mi^2$; and 0.647 $ft^3/s/mi^2$ for fourteen stations representing discharge from unconsolidated clastic sediments of the Coastal Plain Province.

Table 5. Mean-annual stream discharge, estimated annual and mean-annual baseflow, and unit-area mean-annual baseflow at selected gaged streams in the Alabama River basin, Subarea 8

[S, solution-conduit aquifer; P, porous-media aquifer]

Station number	Station name	Type of stream	Drainage area (square miles)	Major aquifer type	Recession index: Winter (days)	Recession index: Summer (days)	Water year	Flow conditions	Mean-annual stream discharge[1] (cubic feet per second)	Annual baseflow[2,3] (cubic feet per second)	Mean-annual baseflow[3,4] (cubic feet per second)	Unit-area mean-annual baseflow[3,5] (cubic feet per second per square mile)
02421000	Catoma Creek near Montgomery, Ala.	tributary	290	P	38	25	1967	Low	236	20		
							1978	Average	368	24	25	0.086
							1989	High	635	32		
02422500	Mulberry Creek at Jones, Ala.	do.	203	P	120	75	1986	Low	105	80		
							1987	Average	324	205	188	.926
							1983	High	483	280		
02423000	Alabama River at Selma, Ala.	regional	17,095	P	130	85	1904	Low	12,500	8,700		
							1908	Average	27,820	17,500	15,500	.907
							1909	High	33,920	20,400		
02424000	Cahaba River at Centreville, Ala.	do.	1,027	P	71	49	1931	Low	831	490		
							1958	Average	1,551	750	763	.743
							1949	High	2,827	1,050		
02424500	Cahaba River at Sprott, Ala.	do.	1,370	P	71	49	1954	Low	1,205	720		
							1951	Average	2,148	1,050	1,100	.803
							1949	High	3,613	1,520		
02424940	Oakmulgee Creek near Augustin, Ala.	tributary	220	P	85	40	1986	Low	100	70		
							1984	Average	296	170	147	.668
							1979	High	444	200		
02425000	Cahaba River near Marion Junction, Ala.	regional	1,766	P	95	50	1954	Low	1,583	965		
							1951	Average	2,604	1,300	1,440	.815
							1949	High	4,470	2,050		
02425200	Big Swamp Creek near Orrville, Ala.	tributary	35.8	P	55	30	1974	Low	32	12		
							1984	Average	51	15	16	.447
							1983	High	90	20		
02425500	Cedar Creek at Minter, Ala.	do.	211	P	85	39	1981	Low	67	27		
							1966	Average	246	70	64	.303
							1961	High	420	94		

Table 5. Mean-annual stream discharge, estimated annual and mean-annual baseflow, and unit-area mean-annual baseflow at selected gaged streams in the Alabama River basin, Subarea 8—Continued

[S, solution-conduit aquifer; P, porous-media aquifer]

Station number	Station name	Type of stream	Drainage area (square miles)	Major aquifer type	Recession index: Winter (days)	Recession index: Summer (days)	Water year	Flow conditions	Mean-annual stream discharge[1] (cubic feet per second)	Annual baseflow[2,3] (cubic feet per second)	Mean-annual baseflow[3,4] (cubic feet per second)	Unit-area mean-annual baseflow[3,5] (cubic feet per second per square mile)
02426000	Boguechitto Creek near Browns, Ala.	do.	95.4	P	40	10	1950	Low	62	18		0.241
							1968	Average	124	21	23	
							1949	High	177	29		
02427700	Turkey Creek at Kimbrough, Ala.	do.	97.5	P	56	33	1986	Low	42	18		
							1987	Average	166	50	44	.451
							1962	High	235	64		
02428500	Big Flat Creek near Fountain, Ala.	do.	247	P	70	35	1963	Low	118	52		
							1965	Average	264	85	96	.389
							1949	High	540	150		
02429000	Limestone Creek near Monroeville, Ala.	do.	121	S	90	52	1969	Low	84	55		
							1958	Average	156	91	99	.818
							1961	High	295	150		
02429500	Alabama River at Claiborne, Ala.	regional	21,967	P	140	70	1904	Low	14,480	10,600		
							1908	Average	32,400	21,300	19,700	.897
							1909	High	43,360	27,200		
02429595	Little River near Uriah, Ala.	tributary	95.2	P	105	80	1972	Low	136	105		
							1973	Average	174	125	125	1.31
							1975	High	262	145		

1/From annually published U.S. Geological Survey data reports, for example: Pearman and others (1994).
2/Estimated using the SWGW program (Mayer and Jones, 1996).
3/Values are reported to three significant digits to maintain the numerical balance of the water budget; implication of accuracy to the degree shown is not intended.
4/Estimated by averaging discharges for low, average, and high flow years for the period of unregulated flow.
5/Discharge divided by drainage area.

The unit-area mean-annual baseflow for the entire drainage of Subarea 8 (22,618 mi^2; table 6) probably is best represented by the results of hydrograph separation using the synthesized streamflow data for the Alabama River at Claiborne, Ala. (table 5). Accordingly, the unit-area mean-annual baseflow determined for the Alabama River at Claiborne, Ala., (0.897 $ft^3/s/mi^2$) was applied to the entire drainage area of Subarea 8 to estimate the mean-annual baseflow at the mouth of the Alabama River (20,300 ft^3/s; table 6).

Table 6. Estimated mean-annual baseflow at selected gaged streams, estimation site, and entering and exiting Subarea 8

[—, not applicable]

Station number or estimation site	Station name	Drainage area (square miles)	Mean-annual stream discharge (cubic feet per second)	Mean-annual baseflow[1/] (cubic feet per second)	Mean unit-area baseflow[1/] (cubic feet per second per square mile)
Cumulative drainage area, stream discharge, and mean-annual baseflow, Alabama River basin at confluence of Coosa and Tallapoosa Rivers		**14,836**	**[2/]21,500**	**[3/]13,800**	**[4/]0.930**
02420000	Alabama River near Montgomery, Ala.	15,087	[5/]23,890	[6/]14,000	—
02423000	Alabama River at Selma, Ala.	17,095	[5/]26,170	[7/]15,500	[4/]0.907
02424000	Cahaba River at Centreville, Ala.	1,027	[5/]1,598	[7/]763	[4/].743
02424500	Cahaba River at Sprott, Ala.	1,370	[5/]2,002	[7/]1.100	[4/].803
02425000	Cahaba River near Marion Junction, Ala.	1,766	[5/]2,840	[7/]1,440	[4/].815
Estimation site	Cahaba River at mouth	1,825	**[5/]2,940**	**[6/]1,490**	—
02427500	Alabama River near Millers Ferry, Ala.	20,600	[5/]30,330	[8/]18,500	—
02428400	Alabama River at Claiborne Lock and Dam, near Monroeville, Ala.	21,473	[5/]33,560	[8/]19,300	—
02429500	Alabama River at Claiborne, Ala.	21,967	[5/]32,540	[7/]19,700	[4/].897
Cumulative drainage area, stream discharge, and mean-annual baseflow, Alabama River basin		**22,618**	**[9/]33,500**	**[9/]20,300**	—

[1/]Values are reported to three significant digits to maintain the numerical balance of the water budget; implication of accuracy to the degree shown is not intended.
[2/]Sum of estimated mean-annual stream discharges from Subareas 5 (Journey and Atkins, 1996) and 6 (Robinson and others, 1996).
[3/]Sum of estimated mean-annual baseflows from Subareas 5 (Journey and Atkins, 1996) and 6 (Robinson and others, 1996).
[4/]Discharge divided by the drainage area.
[5/]From table 3.
[6/]Estimate based on unit-area discharge at upstream stations.
[7/]From table 5.
[8/]Estimate based on unit-area discharge at downstream station.
[9/]Estimate based on unit-area discharge for the Alabama River at Claiborne, Ala.

The mean-annual baseflow in the Alabama River at the confluence of the Coosa and Tallapoosa River is estimated to be 13,800 ft^3/s (table 6). Combined with the mean-annual baseflow in the Cahaba River at Centreville (763 ft^3/s from table 6), the total mean-annual baseflow entering Subarea 8 from Subarea 5, 6, and 7 is 14,600 ft^3/s. The estimated cumulative contribution of mean-annual baseflow at the Alabama River cutoff (exiting Subarea 8) is 20,300 ft^3/s, of which 1,490 ft^3/s is contributed by the Cahaba River basin (table 6). The difference of 5,700 ft^3/s is the estimated mean-annual baseflow in the Alabama River tributaries in Subarea 8. Mean-annual baseflow represents about 61 percent of the mean-annual stream discharge at the mouth of the Alabama River. A downstream profile of mean-annual baseflow of the Alabama River related to drainage area is shown in figure 9 and summarized in table 6.

Drought Flow for 1941, 1954, and 1986

Regional drought periods of 1938-45, 1950-63, and 1984-88 were marked by severe droughts in the years of 1941, 1954, and 1986 in the ACF and ACT River basins. Typically, the lowest mean-annual streamflow for the period of record occurred during one of these years. Streamflow was assumed to be sustained entirely by baseflow near the end of these droughts. Near-synchronous discharge measurements at partial-record gaging stations or daily mean streamflow at continuous-record gaging stations during these periods were assumed to provide a quantitative estimate of near minimum or near minimum baseflow into and exiting Subarea 8. Where available, streamflow data for an interval of a few days were compiled; and where not available, streamflow was estimated using various techniques—discussed below.

Estimated and measured streamflows near the end of the 1941, 1954, and 1986 drought years at selected sites on the Alabama River and its tributaries are listed in tables 7, 8, and 9, respectively, and summarized in table 10. Streamflow during the drought of 1954 represented the minimum baseflow in Subarea 8. Estimated streamflow at the confluence of the Coosa and Tallapoosa Rivers near the end of the 1941, 1954, and 1986 drought years was 2,550, 1,910, and 2,620 ft^3/s, respectively (tables 7-9); streamflow range was 710 ft^3/s and the average streamflow (table 10) was 2,360 ft^3/s. Total streamflow entering Subarea 8 from Subareas 5, 6, and 7 near the end of the 1941, 1954, and 1986 droughts was 2,740, 2,030, and 2,790 ft^3/s, respectively; streamflow range was 760 ft^3/s; and the average streamflow was 2,520 ft^3/s. Estimated streamflows at the Alabama River cutoff near the end of the 1941, 1954, and 1986 droughts were 3,960, 2,730, and 3,670 ft^3/s, respectively; streamflow range was 1,230 ft^3/s, and the average streamflow (table 10) was 3,450 ft^3/s.

Baseflow near the end of these droughts averaged about 17 percent of the estimated mean-annual baseflow at the confluence of the Coosa and Tallapoosa Rivers; about 17 percent of the estimated mean-annual baseflow entering Subarea 8 from Subareas 5, 6, and 7; and about 17 percent of the estimated mean-annual baseflow at the mouth of the Alabama River (end of Subarea 8). Downstream profiles of streamflow related to drainage area for the Alabama and Cahaba Rivers were plotted from estimated and measured streamflow at selected stations for the 1941, 1954, and 1986 drought years (figs. 9, 10). In relation to the conceptual model of ground-water flow and stream-aquifer relations, the mean-annual baseflow estimated for the Alabama River represents ground-water discharge from the local, intermediate, and regional flow regimes. Baseflow during droughts indicate greatly reduced contributions from the local and intermediate flow regimes. Drainage areas, drought flows, and baseflows in the Alabama and Cahaba River basins near the end of the 1941, 1954, and 1986 droughts are plotted in figures 9 and 10 and summarized in tables 10, 11, and 12.

Table 7. Stream discharge during the months of October and November of the drought of 1941, Subarea 8
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1/] (cubic feet per second per square mile)
Estimation site	Coosa River at mouth	tributary	10,161	—	[2/]2,070	—
Estimation site	Tallapoosa River at mouth	do.	4,675	—	[3/]481	—
02410060	Mortar Creek near Elmore, Ala.	do.	76.2	10/23/41	[4/]26	0.341
Estimation site	Mortar Creek at mouth	do.	81.3	—	[5/]28	—
02420000	Alabama River near Montgomery, Ala.	regional	15,087	—	[6/]2,640	.175
02420500	Autauga Creek at Prattville, Ala.	tributary	116	10/23/41	[7/]64	.552
Estimation site	Autauga Creek at mouth	do.	121	—	[8/]67	—
02421000	Catoma Creek near Montgomery	do.	290	10/23/41	[9/]3	.010
Estimation site	Catoma Creek at mouth	do.	345	—	[10/]3	—
02421175	Pintlalla Creek near Montgomery, Ala.	do.	250	10/21/41	[4/]1	.004
Estimation site	Pintlalla Creek at mouth	do.	263	—	[11/]1	—
Estimation site	Tallawassee Creek at mouth	do.	36.5	—	[12/].1	—
02421280	Swift Creek at Autaugaville, Ala.	do.	135	10/18/41	[4/]63	.467
Estimation site	Swift Creek at mouth	do.	137	—	[13/]64	—
Estimation site	Howard Creek at mouth	do.	7.7	—	[13/]4	—
Estimation site	Beaver Creek at mouth	do.	18	—	[13/]8	—
02421300	Ivy Creek at Mulberry, Ala.	do.	10.7	10/23/41	[9/]3	.280
Estimation site	Ivy Creek at mouth	do.	21	—	[14/]6	—
02421500	Big Swamp Creek near Hayneville, Ala.	do.	123	10/23/41	[7/]0	0
02422000	Big Swamp Creek near Lowndesboro, Ala.	do.	244	10/23/41	[7/]1	.004
Estimation sit	Big Swamp Creek at mouth	do.	280	—	[15/]1	—
02422075	Old Town Creek at Benton	do.	26.7	10/21/41	[4/].9	.034
Estimation site	Old Town Creek at mouth	do.	30	—	[16/]1	—
02422130	Little Mulberry Creek near Billingsley, Ala.	do.	55.1	10/23/41	[17/]16	.290
Estimation site	Little Mulberry Creek at mouth	do.	117	—	[18/]34	—
02422500	Mulberry Creek at Jones, Ala.	do.	203	10/23/41	[7/]69	.340
Estimation site	Mulberry Creek at mouth	do.	276	—	[19/]94	—
Estimation site	Soapstone Creek at mouth	do.	32	—	[15/].1	—
Estimation site	Beech Creek at mouth	do.	59	—	[20/]8	—
02423000	Alabama River at Selma, Ala.	regional	17,095	—	[21/]2,980	.174
02423030	Valley Creek near Selma, Ala.	tributary	68	10/22/41	[4/]9	.132
Estimation site	Valley Creek at mouth	do.	68.3	—	[20/]9	—
02424000	Cahaba River at Centreville, Ala.	regional	1,027	10/22/41	[7/]188	.183
02424035	Haysop Creek at Brent, Ala.	tributary	40	10/22/41	[17/]4.6	.115
Estimation site	Haysop Creek at mouth	do.	51	—	[22/]6	—
Estimation site	Affonee Creek at mouth	do.	42	—	[19/]14	—
02424250	Blue Girth Creek near Harrisburg, Ala.	do.	32.1	10/22/41	[17/]7.2	.224
Estimation site	Blue Girth Creek at mouth	do.	36	—	[23/]8	—
Estimation site	Wallace Creek at mouth	do.	17	—	[19/]6	—
02424270	Old Town Creek near Heiberger, Ala.	do.	31.2	10/22/41	[17/]5	.160
Estimation site	Old Town Creek at mouth	do.	33.8	—	[24/]5	—
Estimation site	Mill Creek at mouth	do.	24.2	—	[19/]8	—
Estimation site	Goose Creek at mouth	do.	10	—	[19/]3	—

Table 7. Stream discharge during the months of October and November of the drought of 1941, Subarea 8—Continued

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1] (cubic feet per second per square mile)
Estimation site	Waters Creek at mouth	tributary	21	—	[25]3	—
Estimation site	Rice Creek at mouth	do	33.4	—	[25]5	—
Estimation site	Silver Creek at mouth	do.	9.6	—	[25]1	—
Estimation site	Possum Creek at mouth	do.	10.7	—	[25]1	—
02424950	Oakmulgee Creek near Selma, Ala.	do.	233	10/22/41	[4]32	.137
Estimation site	Oakmulgee Creek at mouth	do.	236	—	[25]32	—
Estimation site	Dry Creek at mouth	do.	15.8	—	[25]2	—
02425000	Cahaba River at Marion Junction, Ala.	regional	1,766	10/22/41	[7]411	.233
Estimation site	Childers Creek at mouth	tributary	21.1	—	[25]3	—
Estimation site	Cahaba River at mouth	regional	1,825	—	[26]425	—
Estimation site	Big Swamp Creek at mouth	tributary	40	—	[27]2	—
02425594	Cedar Creek near Belknap, Ala.	do.	373	11/18/41	[4]16	.043
Estimation site	Cedar Creek at mouth	do.	462	—	[27]20	—
Estimation site	Oak Creek at mouth	do.	31	—	[27]1	—
02426500	Boguechitto Creek above Orrville, Ala.	do.	200	10/22/41	[7]0	0
02427000	Boguechitto Creek near Orrville, Ala.	do.	293	10/22/41	[7].1	.0003
Estimation site	Boguechitto Creek at mouth	do.	364	—	[28].1	—
02427100	Chilatchee Creek at Alberta, Ala.	do.	90	11/18/41	[4].2	.002
Estimation site	Chilatchee Creek at mouth	do.	138	—	[29].3	—
02427350	Pine Barren Creek near Camden, Ala.	do.	345	10/24/41	[4]36	.104
Estimation site	Pine Barren Creek at mouth	do.	350	—	[30]36	—
Estimation site	Foster Creek at mouth	do.	17.4	—	[30]2	—
02427500	Alabama River near Millers Ferry, Ala.	regional	20,600	—	[21]3,510	.170
Estimation site	Rockwest Creek at mouth	tributary	26.9	—	[30]3	—
Estimation site	Dixon Creek at mouth	do.	44.8	—	[30]5	—
02427700	Turkey Creek at Kimbrough, Ala.	do.	97.5	10/23/41	[9]2	.021
Estimation site	Beaver Creek at mouth	do.	257	—	[31]5	—
02427865	Pursley Creek above Camden, Ala.	do.	45.1	10/23/41	[9].1	.002
Estimation site	Pursley Creek at mouth	do.	105	—	[32].2	—
Estimation site	Bear Creek at mouth	do.	51.9	—	[33]1	—
Estimation site	McCalls Creek at mouth	do.	49.6	—	[33]1	—
02428300	Tallatchee Creek near Vredenburgh, Ala.	do.	13.2	10/23/41	[9]0	0
Estimation site	Tallatchee Creek at mouth	do.	40.1	—	[34]0	—
Estimation site	Cane Creek at mouth	do.	57	—	[33]1	—
Estimation site	Silver Creek at mouth	do.	34.2	—	[33]1	—
02428500	Big Flat Creek near Fountain, Ala.	do.	247	10/23/41	[4]5.5	.022
Estimation site	Big Flat Creek at mouth	do.	309	—	[33]7	—
02429000	Limestone Creek near Monroeville, Ala.	do.	121	10/23/41	[9]22	.182
Estimation site	Limestone Creek at mouth	do.	177	—	[35]32	—
02429500	Alabama River at Claiborne, Ala.	regional	21,967	—	[21]3,580	.163
Estimation site	Pigeon Creek at mouth	tributary	41.0	—	[35]7	—
02429525	Lovetts Creek near Frisco City, Ala.	tributary	32.5	10/23/41	[17]38	1.17
Estimation site	Lovetts Creek at mouth	do.	94.3	—	[36]110	—

Table 7. Stream discharge during the months of October and November of the drought of 1941, Subarea 8—Continued

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1/] (cubic feet per second per square mile)
Estimation site	Wallers Creek at mouth	do.	35.2	—	[33/]1	—
Estimation site	Sizemore Creek at mouth	tributary	36.5	—	[33/]1	—
02429605	Little River near Little River, Ala.	do.	137	10/23/41	[9/]89	.650
Estimation site	Little River at mouth	do.	141	—	[37/]92	—
Estimation site	Holley Creek at mouth	do.	17.7	—	[33/].4	—
Estimation site	Alabama River at the Alabama River cutoff	regional	22,618	—	[21/]3,960	—

[1/]Discharge divided by the drainage area.
[2/]Robinson and others (1996).
[3/]Journey and Atkins (1996).
[4/]Discharge measurement.
[5/]Estimate based on unit area discharge at Mortar Creek near Elmore.
[6/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the confluence of the Coosa and Tallapoosa Rivers.
[7/]Daily mean discharge.
[8/]Estimate based on unit area discharge at Autauga Creek at Prattville, Ala.
[9/]Estimate based on MOVE.1 statistical correlation with a continuous-record gaging station.
[10/]Estimate based on unit-area discharge at Catoma Creek near Montgomery, Ala.
[11/]Estimate based on unit-area discharge at Pintlalla Creek near Montgomery, Ala.
[12/]Estimate based on unit-area discharge at Big Swamp Creek near Lowndesboro, Ala.
[13/]Estimate based on unit-area discharge at Swift Creek at Autaugaville, Ala.
[14/]Estimate based on unit-area discharge at Ivy Creek at Mulberry, Ala.
[15/]Estimate based on unit-area discharge at Big Swamp Creek near Lowndesboro, Ala.
[16/]Estimate based on unit-area discharge at Old Town Creek at Benton, Ala.
[17/]Estimate based on graphical correlation with a continuous-record gaging station.
[18/]Estimate based on unit-area discharge at Little Mulberry Creek near Billingsley, Ala.
[19/]Estimate based on unit-area discharge at Mulberry Creek at Jones, Ala.
[20/]Estimate based on unit-area discharge at Valley Creek at Selma, Ala.
[21/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the nearest upstream Alabama River station.
[22/]Estimate based on unit-area discharge at Haysop Creek at Brent, Ala.
[23/]Estimate based on unit-area discharge at Blue Girth Creek near Harrisburg, Ala.
[24/]Estimate based on unit-area discharge at Old Town Creek near Heiberger, Ala.
[25/]Estimate based on unit-area discharge at Oakmulgee Creek near Selma, Ala.
[26/]Estimate based on unit-area discharge at Cahaba River at Marion Junction, Ala.
[27/]Estimate based on unit-area discharge at Cedar Creek near Belknap, Ala.
[28/]Estimate based on unit-area discharge at Boguechitto Creek near Orrville, Ala.
[29/]Estimate based on unit-area discharge at Chilatchee Creek at Alberta, Ala.
[30/]Estimate based on unit-area discharge at Pine Barren Creek near Camden, Ala.
[31/]Estimate based on unit-area discharge at Turkey Creek at Kimbrough, Ala.
[32/]Estimate based on unit-area discharge at Pursley Creek above Camden, Ala.
[33/]Estimate based on unit-area discharge at Big Flat Creek near Fountain, Ala.
[34/]Estimate based on unit-area discharge at Tallatchee Creek near Vredenburgh, Ala.
[35/]Estimate based on unit-area discharge at Limestone Creek near Monroeville, Ala.
[36/]Estimate based on unit area discharge at Lovetts Creek near Frisco City, Ala.
[37/]Estimate based on unit-area discharge at Little River near Little River, Ala.

Table 8. Stream discharge during the month of September of the drought of 1954, Subarea 8
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1] (cubic feet per second per square mile)
Estimation site	Coosa River at mouth	tributary	10,161	—	[2]1,780	—
Estimation site	Tallapoosa River at mouth	do.	4,675	—	[3]126	—
02410060	Mortar Creek near Elmore, Ala.	do.	76.2	09/30/54	[4]8	0.105
Estimation site	Mortar Creek at mouth	do.	81.3	—	[5]8	—
02420000	Alabama River near Montgomery, Ala.	regional	15,087	—	[6]1,930	.128
02420500	Autauga Creek at Prattville, Ala.	tributary	116	09/30/54	[7]49	.422
Estimation site	Autauga Creek at mouth	do.	121	—	[8]51	—
02421000	Catoma Creek near Montgomery, Ala.	do.	290	09/30/54	[7]0	0
Estimation site	Catoma Creek at mouth	do.	345	—	[9]0	—
02421175	Pintlalla Creek near Montgomery, Ala.	do.	250	09/30/54	[4]2	.008
Estimation site	Pintlalla Creek at mouth	do.	263	—	[10]2	—
Estimation site	Tallawassee Creek at mouth	do.	36.5	—	[11]0	—
02421280	Swift Creek at Autaugaville, Ala.	do.	135	09/30/54	[12]32	.237
Estimation site	Swift Creek at mouth	do.	137	—	[13]32	—
Estimation site	Howard Creek at mouth	do.	7.7	—	[14]1	—
Estimation site	Beaver Creek at mouth	do.	18	—	[14]3	—
02421300	Ivy Creek at Mulberry, Ala.	do.	10.7	09/30/54	[14]1	.093
Estimation site	Ivy Creek at mouth	do.	21	—	[15]2	—
02422000	Big Swamp Creek near Lowndesboro, Ala.	do.	244	09/30/54	[7]0	0
Estimation site	Big Swamp Creek at mouth	do.	280	—	[11]0	—
Estimation site	Old Town Creek at mouth	do.	30	—	[11]0	—
02422130	Little Mulberry Creek near Billingsley, Ala.	do.	55.1	09/30/54	[12]2	.036
Estimation site	Little Mulberry Creek at mouth	do.	117	—	[16]4	—
02422500	Mulberry Creek at Jones, Ala.	do.	203	09/30/54	[7]30	.148
Estimation site	Mulberry Creek at mouth	do.	276	—	[14]41	—
Estimation site	Soapstone Creek at mouth	do.	32	—	[11]0	—
Estimation site	Beech Creek at mouth	do.	59	—	[14]9	—
02423000	Alabama River at Selma, Ala.	regional	17,095	—	[17]2,100	.123
02423030	Valley Creek near Selma, Ala.	tributary	68	09/30/54	[12]4	.059
Estimation site	Valley Creek at mouth	do.	68.3	—	[18]4	—
02424000	Cahaba River at Centreville, Ala.	regional	1,027	09/30/54	[7]124	.121
02424035	Haysop Creek at Brent, Ala.	tributary	40	09/30/54	[12]2	.050
Estimation site	Haysop Creek at mouth	do.	51	—	[19]3	—
Estimation site	Affonee Creek at mouth	do.	42	—	[14]6	—
02424250	Blue Girth Creek near Harrisburg, Ala.	do.	32.1	09/30/54	[12]4	.125
Estimation site	Blue Girth Creek at mouth	do.	36	—	[20]4	—
Estimation site	Wallace Creek at mouth	do.	17	—	[14]3	—
02424270	Old Town Creek near Heiberger, Ala.	do.	31.2	09/30/54	[12]1	.032
Estimation site	Old Town Creek at mouth	do.	33.8	—	[21]1	—
Estimation site	Mill Creek at mouth	do.	24.2	—	[14]4	—
02424500	Cahaba River at Sprott, Ala.	regional	1,370	09/30/54	[7]201	.147
Estimation site	Goose Creek at mouth	tributary	10	—	[14]1	—
Estimation site	Waters Creek at mouth	do.	21	—	[14]3	—

Table 8. Stream discharge during the month of September of the drought of 1954, Subarea 8—Continued
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1] (cubic feet per second per square mile)
Estimation site	Rice Creek at mouth	tributary	33.4	—	[14]5	—
Estimation site	Silver Creek at mouth	do.	9.6	—	[14]1	—
Estimation site	Possum Creek at mouth	do.	10.7	—	[14]2	—
02424950	Oakmulgee Creek near Selma, Ala.	do.	233	09/30/54	[4]13	.056
Estimation site	Oakmulgee Creek at mouth	do.	236	—	[22]13	—
Estimation site	Dry Creek at mouth	do.	15.8	—	[14]2	—
02425000	Cahaba River at Marion Junction, Ala.	regional	1,766	09/30/54	[8]227	.128
Estimation site	Childers Creek at mouth	tributary	21.1	—	[14]3	—
Estimation site	Cahaba River at mouth	regional	1,825	—	[23]234	—
02425200	Big Swamp Creek near Orrville, Ala.	tributary	35.8	09/30/54	[4].1	.003
Estimation site	Big Swamp Creek at mouth	do.	40	—	[24].1	—
02425500	Cedar Creek at Minter, Ala.	do.	211	09/30/54	[7]1.6	.008
Estimation site	Cedar Creek at mouth	do.	462	—	[25]4	—
Estimation site	Oak Creek at mouth	do.	31	—	[25].2	—
02426000	Boguechitto Creek near Browns, Ala.	do.	95.4	09/30/54	[12]0	0
Estimation site	Boguechitto Creek at mouth	do.	364	—	[26]0	—
02427100	Chilatchee Creek at Alberta, Ala.	do.	90	09/30/54	[12]0	0
Estimation site	Chilatchee Creek at mouth	do.	138	—	[27]0	—
02427250	Pine Barren Creek near Snow Hill, Ala.	do.	261	09/30/54	[4]11	.042
Estimation site	Pine Barren Creek at mouth	do.	350	—	[28]15	—
Estimation site	Foster Creek at mouth	do.	17.4	—	[29].1	—
02427500	Alabama River near Millers Ferry, Ala.	regional	20,600	—	[17]2,370	.115
Estimation site	Rockwest Creek at mouth	tributary	26.9	—	[29].1	—
Estimation site	Dixon Creek at mouth	do.	44.8	—	[29].1	—
02427700	Turkey Creek at Kimbrough, Ala.	do.	97.5	09/30/54	[4].2	.002
Estimation site	Beaver Creek at mouth	do.	257	—	[30].5	—
02427865	Pursley Creek above Camden, Ala.	do.	45.1	09/30/54	[4]0	0
Estimation site	Pursley Creek at mouth	do.	105	—	[31]0	—
Estimation site	Bear Creek at mouth	do.	51.9	—	[29].2	—
Estimation site	McCalls Creek at mouth	do.	49.6	—	[29].1	—
02428300	Tallatchee Creek near Vredenburgh, Ala.	do.	13.2	09/30/54	[4]0	0
Estimation site	Tallatchee Creek at mouth	do.	40.1	—	[32]0	—
Estimation site	Cane Creek at mouth	do.	57	—	[29].2	—
Estimation site	Silver Creek at mouth	do.	34.2	—	[29].1	—
02428500	Big Flat Creek near Fountain, Ala.	do.	247	09/30/54	[7].7	.003
Estimation site	Big Flat Creek at mouth	do.	309	—	[29]1	—
02429000	Limestone Creek near Monroeville, Ala.	do.	121	09/30/54	[7]18	.149
Estimation site	Limestone Creek at mouth	do.	177	—	[33]26	—
02429500	Alabama River at Claiborne, Ala.	regional	21,967	—	[17]2,400	.109
Estimation site	Pigeon Creek at mouth	tributary	41.0	—	[33]6	—
02429525	Lovetts Creek near Frisco City, Ala.	do.	32.5	09/30/54	[12]30	.923
Estimation site	Lovetts Creek at mouth	do.	94.3	—	[34]87	—
Estimation site	Wallers Creek at mouth	do.	35.2	—	[33]5	—

Table 8. Stream discharge during the month of September of the drought of 1954, Subarea 8—Continued
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge[1/] (cubic feet per second per square mile)
Estimation site	Sizemore Creek at mouth	do.	36.5	—	[33/]5	—
02429605	Little River near Little River, Ala.	do.	137	09/30/54	[4/]75	.547
Estimation site	Little River at mouth	tributary	141	—	[35/]77	—
Estimation site	Holley Creek at mouth	do.	17.7	—	[33/]3	—
Estimation site	Alabama River at the Alabama River cutoff	regional	22,618	—	[17/]2,730	—

[1/]Discharge divided by the drainage area.
[2/]Robinson and others (1996).
[3/]Journey and Atkins (1996).
[4/]Estimate based on MOVE.1 statistical correlation with a continuous-record gaging station.
[5/]Estimate based on unit-area discharge at Mortar Creek near Elmore, Ala.
[6/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the confluence of the Coosa and Tallapoosa Rivers.
[7/]Daily mean discharge.
[8/]Estimate based on unit-area discharge at Autauga Creek at Prattville, Ala.
[9/]Estimate based on unit-area discharge at Catoma Creek near Montgomery, Ala.
[10/]Estimate based on unit-area discharge at Pintlalla Creek near Montgomery, Ala.
[11/]Estimate based on unit-area discharge at Big Swamp Creek near Lowndesboro, Ala.
[12/]Estimate based on graphical correlation with a continuous-record gaging station.
[13/]Estimate based on unit-area discharge at Swift Creek at Autaugaville, Ala.
[14/]Estimate based on unit-area discharge at Mulberry Creek at Jones, Ala.
[15/]Estimate based on unit-area discharge at Ivy Creek at Mulberry, Ala.
[16/]Estimate based on unit-area discharge at Little Mulberry Creek near Billingsley, Ala.
[17/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the nearest upstream Alabama River station.
[18/]Estimate based on unit-area discharge at Valley Creek near Selma, Ala.
[19/]Estimate based on unit-area discharge at Haysop Creek at Brent, Ala.
[20/]Estimate based on unit-area discharge at Blue Girth Creek near Harrisburg, Ala.
[21/]Estimate based on unit-area discharge at Old Town Creek near Heiberger, Ala.
[22/]Estimate based on unit-area discharge at Oakmulgee Creek near Selma, Ala.
[23/]Estimate based on unit-area discharge at Cahaba River at Marion Junction, Ala.
[24/]Estimate based on unit-area discharge at Big Swamp Creek near Orrville, Ala.
[25/]Estimate based on unit-area discharge at Cedar Creek at Minter, Ala.
[26/]Estimate based on unit-area discharge at Boguechitto Creek near Orrville, Ala.
[27/]Estimate based on unit-area discharge at Chilatchee Creek at Alberta, Ala.
[28/]Estimate based on unit-area discharge at Pine Barren Creek near Snow Hill, Ala.
[29/]Estimate based on unit-area discharge at Big Flat Creek near Fountain, Ala.
[30/]Estimate based on unit-area discharge at Turkey Creek at Kimbrough, Ala.
[31/]Estimate based on unit-area discharge at Pursley Creek above Camden, Ala.
[32/]Estimate based on unit-area discharge at Tallatchee Creek near Vredenburgh, Ala.
[33/]Estimate based on unit-area discharge at Limestone Creek near Monroeville, Ala.
[34/]Estimate based on unit-area discharge at Lovetts Creek near Frisco City, Ala.
[35/]Estimate based on unit-area discharge at Little River near Little River, Ala.

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 8
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)[1]
Estimation site	Coosa River at mouth	tributary	10,161	—	[2]2,170	—
Estimation site	Tallapoosa River at mouth	do.	4,675	—	[3]448	—
02410060	Mortar Creek near Elmore, Ala.	do.	76.2	07/10/86	[4]9	0.118
Estimation site	Mortar Creek at mouth	do.	81.3	—	[5]10	—
02420000	Alabama River near Montgomery, Ala.	regional	15,087	—	[6]2,650	.176
02420500	Autauga Creek at Prattville, Ala.	tributary	116	07/10/86	[4]48	.414
Estimation site	Autauga Creek at mouth	do.	121	—	[7]50	—
02421000	Catoma Creek near Montgomery, Ala.	do.	290	07/10/86	[8].5	.002
Estimation site	Catoma Creek at mouth	do.	345	—	[9].7	—
02421175	Pintlalla Creek near Montgomery, Ala.	do.	250	07/10/86	[4].8	.003
Estimation site	Pintlalla Creek at mouth	do.	263	—	[10].8	—
02421205	Tallawassee Creek near Robinson Bend, Ala.	do.	29.3	07/10/86	[11]10	.341
Estimation site	Tallawassee Creek at mouth	do.	36.5	—	[12]12	—
02421280	Swift Creek at Autaugaville, Ala.	do.	135	07/10/86	[11]36	.267
Estimation site	Swift Creek at mouth	do.	137	—	[13]37	—
Estimation site	Howard Creek at mouth	do.	7.7	—	[14]1	—
Estimation site	Beaver Creek at mouth	do.	18	—	[14]3	—
02421300	Ivy Creek at Mulberry, Ala.	do.	10.7	07/10/86	[4]2	.187
Estimation site	Ivy Creek at mouth	do.	21	—	[15]4	—
02422000	Big Swamp Creek near Lowndesboro, Ala.	do.	244	07/10/86	[4].1	.0004
Estimation site	Big Swamp Creek at mouth	do.	280	—	[16].1	—
Estimation site	Old Town Creek at mouth	do.	30	—	[9].1	—
02422130	Little Mulberry Creek near Billingsley, Ala.	do.	55.1	07/10/86	[11]4	.073
Estimation site	Little Mulberry Creek at mouth	do.	117	—	[17]9	—
02422500	Mulberry Creek at Jones, Ala.	do.	203	07/10/86	[8]37	.182
Estimation site	Mulberry Creek at mouth	do.	276	—	[14]50	—
Estimation site	Soapstone Creek at mouth	do.	32	—	[9].1	—
Estimation site	Beech Creek at mouth	do.	59	—	[14]11	—
02423030	Valley Creek near Selma, Ala.	do.	68	07/10/86	[11]5	.074
Estimation site	Valley Creek at mouth	do.	68.3	—	[18]5	—
02424000	Cahaba River at Centreville, Ala.	regional	1,027	07/10/86	[8]169	.165
02424035	Haysop Creek at Brent, Ala.	tributary	40	07/10/86	[11]2	.050
Estimation site	Haysop Creek at mouth	do.	51	—	[19]3	—
Estimation site	Affonee Creek at mouth	do.	42	—	[14]8	—
02424250	Blue Girth Creek near Harrisburg, Ala.	do.	32.1	07/10/86	[11]5	.156
Estimation site	Blue Girth Creek at mouth	do.	36	—	[20]6	—
Estimation site	Wallace Creek at mouth	do.	17	—	[14]3	—
02424270	Old Town Creek near Heiberger, Ala.	do.	31.2	07/10/86	[11]2	.064
Estimation site	Old Town Creek at mouth	do.	33.8	—	[21]2	—
Estimation site	Mill Creek at mouth	do.	24.2	—	[14]4	—
Estimation site	Goose Creek at mouth	do.	10	—	[14]2	—
Estimation site	Waters Creek at mouth	do.	21	—	[22]2	—
Estimation site	Rice Creek at mouth	do.	33.4	—	[22]3	—

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 8—Continued
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)[1]
Estimation site	Silver Creek at mouth	tributary	9.6	—	[22]1	—
Estimation site	Possum Creek at mouth	do.	10.7	—	[22]1	—
02424940	Oakmulgee Creek near Augustin, Ala.	do.	220	07/10/86	[8]17	.077
Estimation site	Oakmulgee Creek at mouth	do.	236	—	[22]18	—
Estimation site	Dry Creek at mouth	do.	15.8	—	[22]1	—
02425000	Cahaba River at Marion Junction, Ala.	regional	1,766	07/10/86	[8]333	.189
Estimation site	Childers Creek at mouth	tributary	21.1	—	[22]2	—
Estimation site	Cahaba River at mouth	regional	1,825	—	[23]345	—
02425200	Big Swamp Creek near Orrville, Ala.	tributary	35.8	07/10/86	[4].5	.014
Estimation site	Big Swamp Creek at mouth	do.	40	—	[24].6	—
02425595	Cedar Creek near Berlin, Ala.	do.	378	07/10/86	[4]13	.034
Estimation site	Cedar Creek at mouth	do.	462	—	[25]16	—
Estimation site	Oak Creek at mouth	do.	31	—	[26].8	—
02426000	Boguechitto Creek near Browns, Ala.	do.	95.4	07/10/86	[4].3	.003
Estimation site	Boguechitto Creek at mouth	do.	364	—	[27]1	—
02427100	Chilatchee Creek at Alberta, Ala.	do.	90	07/10/86	[11].04	.0004
Estimation site	Chilatchee Creek at mouth	do.	138	—	[28].1	—
02427250	Pine Barren Creek near Snow Hill, Ala.	do.	261	07/10/86	[4]34	.130
Estimation site	Pine Barren Creek at mouth	do.	350	—	[29]46	—
Estimation site	Foster Creek at mouth	do.	17.4	—	[26].4	—
Estimation site	Rockwest Creek at mouth	do.	26.9	—	[26].7	—
Estimation site	Dixon Creek at mouth	do.	44.8	—	[26]1	—
02427700	Turkey Creek at Kimbrough, Ala.	do.	97.5	07/10/86	[8]2.5	.026
Estimation site	Beaver Creek at mouth	do.	257	—	[26]7	—
02427865	Pursley Creek above Camden, Ala.	do.	45.1	07/10/86	[4].1	.002
Estimation site	Pursley Creek at mouth	do.	105	—	[30].2	—
Estimation site	Bear Creek at mouth	do.	51.9	—	[26]1	—
Estimation site	McCalls Creek at mouth	do.	49.6	—	[26]1	—
02428300	Tallatchee Creek near Vredenburgh, Ala.	do.	13.2	07/10/86	[4]0	0
Estimation site	Tallatchee Creek at mouth	do.	40.1	—	[31]0	—
Estimation site	Cane Creek at mouth	do.	57	—	[26]1	—
Estimation site	Silver Creek at mouth	do.	34.2	—	[26].9	—
02428400	Alabama River at Claiborne Lock and Dam, near Monroeville, Ala.	regional	21,473	—	[32]3,330	.155
02428500	Big Flat Creek near Fountain, Ala.	tributary	247	07/10/86	[4]7	.028
Estimation site	Big Flat Creek at mouth	do.	309	—	[33]9	—
02429000	Limestone Creek near Monroeville, Ala.	do.	121	07/10/86	[4]30	.248
Estimation site	Limestone Creek at mouth	do.	177	—	[34]44	—
Estimation site	Pigeon Creek at mouth	do.	41.0	—	[26]1	—
02429525	Lovetts Creek near Frisco City, Ala.	do.	32.5	07/10/86	[11]36	1.11
Estimation site	Lovetts Creek at mouth	do.	94.3	—	[35]105	—
Estimation site	Wallers Creek at mouth	do.	35.2	—	[26].9	—

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 8—Continued
[—, not applicable]

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)[1/]
Estimation site	Sizemore Creek at mouth	tributary	36.5	—	[26/]1	—
02429605	Little River near Little River, Ala.	do.	137	07/10/86	[4/]89	.650
Estimation site	Little River at mouth	do.	141	—	[36/]92	—
Estimation site	Holley Creek at mouth	do.	17.7	—	[26/].5	—
Estimation site	Alabama River at the Alabama River cutoff	regional	22,618	—	[32/]3,670	—

[1/]Discharge divided by the drainage area.
[2/]Robinson and others (1996).
[3/]Journey and Atkins (1996).
[4/]Estimate based on MOVE.1 statistical correlation with a continuous-record gaging station.
[5/]Estimate based on unit-area discharge at Mortar Creek near Elmore.
[6/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the confluence of the Coosa and Tallapoosa Rivers.
[7/]Estimate based on unit-area discharge at Autauga Creek at Prattville, Ala.
[8/]Daily mean discharge.
[9/]Estimate based on unit-area discharge at Catoma Creek near Montgomery, Ala.
[10/]Estimate based on unit-area discharge at Pintlalla Creek near Montgomery, Ala.
[11/]Estimate based on graphical correlation with a continuous-record gaging station.
[12/]Estimate based on unit-area discharge at Tallawassee Creek near Robinson Bend, Ala.
[13/]Estimate based on unit-area discharge at Swift Creek at Autaugaville, Ala.
[14/]Estimate based on unit-area discharge at Mulberry Creek at Jones, Ala.
[15/]Estimate based on unit-area discharge at Ivy Creek at Mulberry, Ala.
[16/]Estimate based on unit-area discharge at Big Swamp Creek near Lowndesboro, Ala.
[17/]Estimate based on unit-area discharge at Little Mulberry Creek near Billingsley, Ala.
[18/]Estimate based on unit-area discharge at Valley Creek near Selma, Ala.
[19/]Estimate based on unit-area discharge at Haysop Creek at Brent, Ala.
[20/]Estimate based on unit-area discharge at Blue Girth Creek near Harrisburg, Ala.
[21/]Estimate based on unit-area discharge at Old Town Creek near Heiberger, Ala.
[22/]Estimate based on unit-area discharge at Oakmulgee Creek near Augustin, Ala.
[23/]Estimate based on unit-area discharge at Cahaba River at Marion Junction, Ala.
[24/]Estimate based on unit-area discharge at Big Swamp Creek near Orrville, Ala.
[25/]Estimate based on unit-area discharge at Cedar Creek near Berlin, Ala.
[26/]Estimate based on unit-area discharge at Turkey Creek at Kimbrough, Ala.
[27/]Estimate based on unit-area discharge at Boguechitto Creek near Orrville, Ala.
[28/]Estimate based on unit-area discharge at Chilatchee Creek at Alberta, Ala.
[29/]Estimate based on unit-area discharge at Pine Barren Creek near Snow Hill, Ala.
[30/]Estimate based on unit-area discharge at Pursley Creek above Camden, Ala.
[31/]Estimate based on unit-area discharge at Tallatchee Creek near Vredenburgh, Ala.
[32/]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this and the nearest upstream Alabama River station.
[33/]Estimate based on unit-area discharge at Big Flat Creek near Fountain, Ala.
[34/]Estimate based on unit-area discharge at Limestone Creek near Monroeville, Ala.
[35/]Estimate based on unit-area discharge at Lovetts Creek near Frisco City, Ala.
[36/]Estimate based on unit-area discharge at Little River near Little River, Ala.

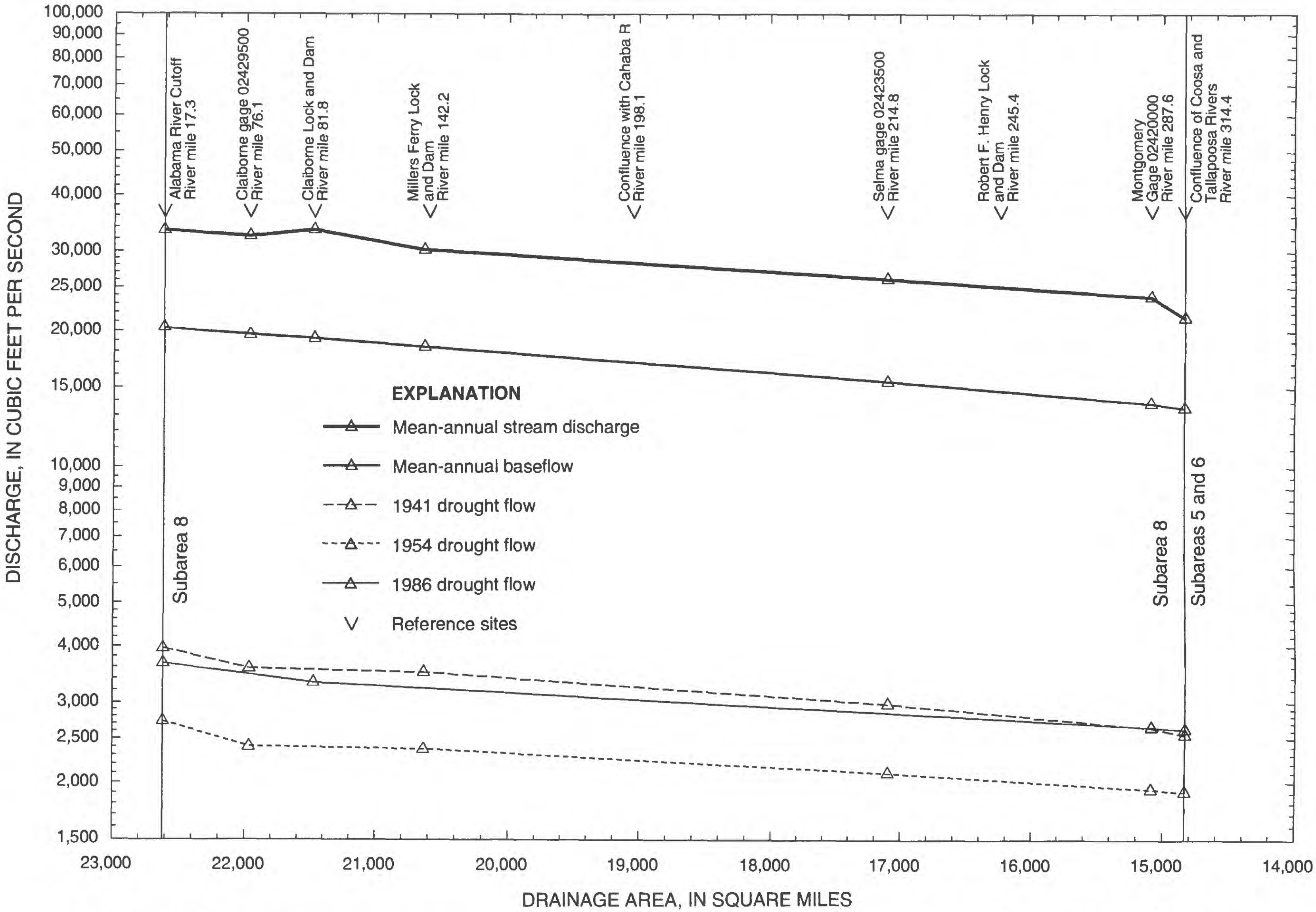


Figure 9. Relations among mean-annual stream discharge, mean-annual baseflow, and drought flow, Alabama River, Subarea 8. [Note: Triangles represent estimated or measured discharges; lines connecting triangles represent interpolated discharge. River mile is measured upstream from the mouth of the Alabama River.]

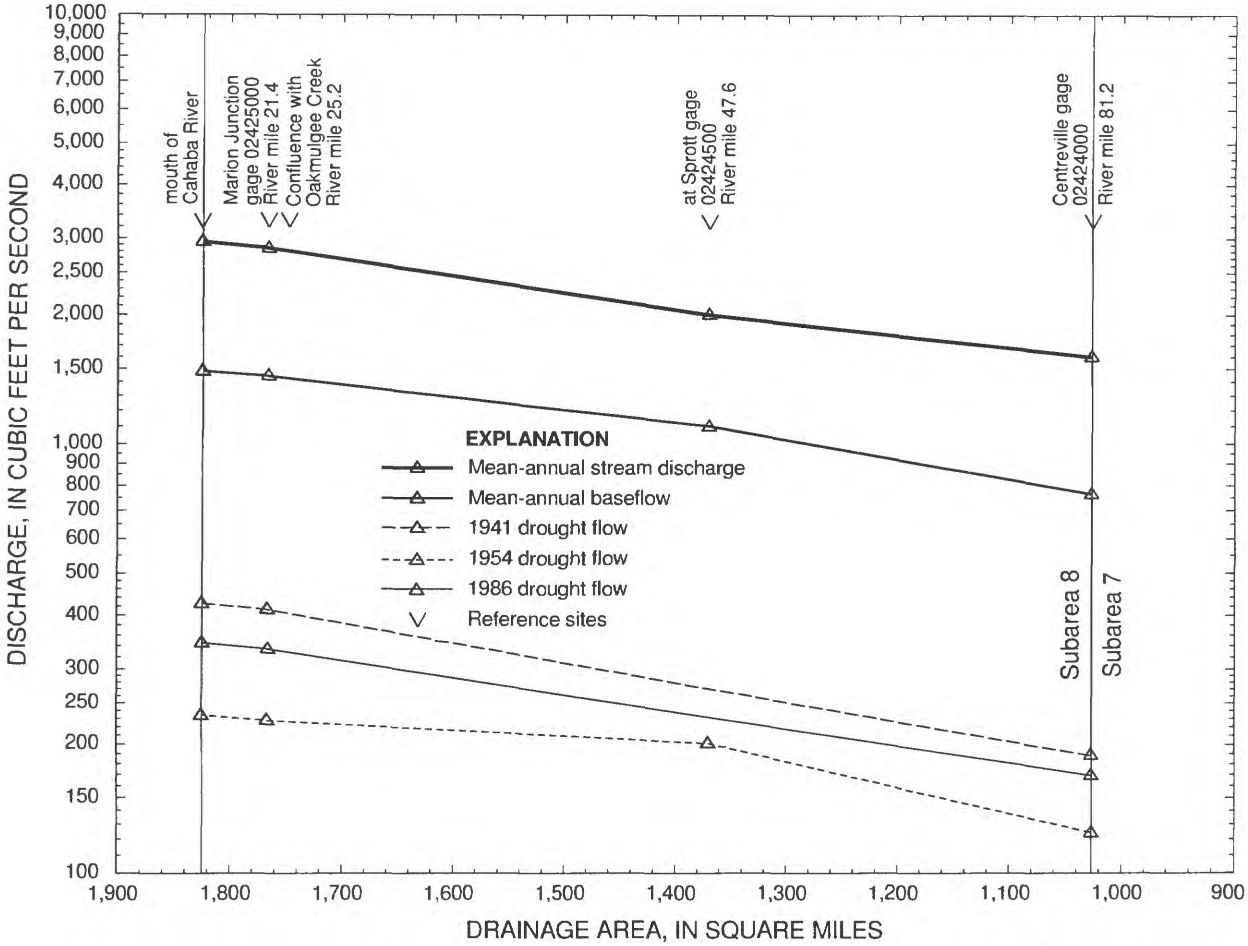


Figure 10. Relations among mean-annual stream discharge, mean-annual baseflow, and drought flow, Cahaba River, Subarea 8. [Note: Triangles represent estimated or measured discharges; lines connecting triangles represent interpolated discharge. River mile is measured upstream from the mouth of the Cahaba River.]

Table 10. Relations among mean-annual stream discharge, estimated mean-annual baseflow, and drought flow in the Alabama River, Subarea 8

[Mean-annual stream discharge is mean for the period of record; —, no available data]

Station number or estimation site	Station name	Drainage area (square miles)	Stream discharge, in cubic feet per second				
			Mean-annual stream discharge[1/]	Estimated mean-annual baseflow[2/]	Drought of 1941[3/]	Drought of 1954[4/]	Drought of 1986[5/]
Estimation site	Alabama River at confluence of Coosa and Tallapoosa Rivers	14,836	21,500	13,800	2,550	1,910	2,620
02420000	Alabama River near Montgomery, Ala.	15,087	23,890	14,000	2,640	1,930	2,650
02423000	Alabama River at Selma, Ala.	17,095	26,170	15,500	2,980	2,100	—
02427500	Alabama River near Millers Ferry, Ala.	20,600	30,330	18,500	3,510	2,370	—
02428400	Alabama River at Claiborne Lock and Dam near Monroeville, Ala.	21,473	33,560	19,300	—	—	3,330
02429500	Alabama River at Claiborne, Ala.	21,967	32,540	19,700	3,580	2,400	—
Estimation site	Alabama River at the Alabama River cutoff	22,618	33,500	20,300	3,960	2,730	3,670

[1/]From table 3 and 6.
[2/]From tables 5 and 6.
[3/]From table 7.
[4/]From table 8.
[5/]From table 9.

Table 11. Relations among mean-annual stream discharge, estimated mean-annual baseflow, and drought flow in the Cahaba River, Subarea 8

[Mean-annual stream discharge is mean for the period of record; —, no available data]

Station number or estimation site	Station name	Drainage area (square miles)	Stream discharge, in cubic feet per second				
			Mean-annual stream discharge[1/]	Estimated mean-annual baseflow[2/]	Drought of 1941[3/]	Drought of 1954[4/]	Drought of 1986[5/]
02424000	Cahaba River at Centreville, Ala.	1,027	1,598	763	188	124	169
02424500	Cahaba River at Sprott, Ala.	1,370	2,002	1,100	—	201	—
02425000	Cahaba River near Marion Junction, Ala.	1,766	2.840	1,440	411	227	333
Estimation site	Cahaba River at mouth	1,825	2,940	1,490	425	234	345

[1/]From tables 3 and 6.
[2/]From tables 5 and 6.
[3/]From table 7.
[4/]From table 8.
[5/]From table 9.

Table 12. Estimated drought flows and mean-annual baseflow in the Alabama River basin; and ratio of average drought flow to mean-annual baseflow, Subarea 8

	Drought flows, in cubic feet per second				Mean-annual baseflow[4/], (in cubic feet per second	Ratio of average drought flow to mean-annual baseflow (percent)
	1941[1/]	1954[2/]	1986[3/]	Average drought flow		
Flow entering Subarea 8	2,740	2,030	2,790	2,520	14,600	17
Flow exiting Subarea 8	**3,960**	**2,730**	**3,670**	[5/]**3,450**	**20,300**	**17**

[1/]From table 7.
[2/]From table 8.
[3/]From table 9.
[4/]From tables 6, 10, and 11.
[5/]Average drought flow exiting Subarea 8, 1941, 1954, and 1986.

GROUND-WATER UTILIZATION AND GENERAL DEVELOPMENT POTENTIAL

Ground-water utilization is defined as the ratio of ground-water use in 1990 to mean-annual ground-water recharge. The degree of ground-water utilization is scale dependent. For example, local ground-water pumping may result in substantial storage change and water-level declines near a center of pumping; whereas, such pumping relative to the entire Subarea would be small compared to mean-annual recharge.

Ground-water use of about 83 ft^3/s in 1990 in Subarea 8 represented 0.4 percent of the mean-annual baseflow and 2.4 percent of the average drought flow near the end of the droughts of 1941, 1954, and 1986 (table 13). For the worst-case scenario, in which flow decreased to the minimum during the period of analysis, 1990 ground-water use represented 3.0 percent of the minimum drought flows.

Table 13. Relation between 1990 ground-water use and ground-water discharge during mean-annual baseflow, average drought flow, and drought flow, Subarea 8

Ground-water use, 1990 (cubic feet per second)	Baseflow to the Alabama River and tributaries (cubic feet per second)			Ratio of ground-water use to baseflow (percent)		
	Mean-annual baseflow	Average drought baseflow	Minimum drought baseflow	Mean-annual baseflow	Average drought baseflow	Minimum drought baseflow
[1/]83.2	**20,300**	**3,450**	**[2/]2,730**	**0.4**	**2.4**	**3.0**

[1/]From Baker and Mooty (1993).

[2/]Minimum stream discharge during 1954 drought.

Because ground-water use in Subareas 5 and 6 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subareas 5 and 6 in Georgia probably would have little effect on the quantity of ground water and surface water in Alabama. In addition, ground-water use in Subarea 3 in Georgia probably has no effect on the quantity of ground water and surface water in the Alabama River basin (Subarea 8) because of the lack of hydraulic connection between Subareas 3 and 8; similarly, ground-water use in Subarea 8 in Alabama probably has no effect on the quantity of ground water and surface water in Subarea 3.

A general assessment of ground-water development potential in Subarea 8 would reflect, in part, the cumulative effects of current and anticipated future hydrologic stresses imposed on the ground-water resources, and to a lesser extent, the current availability of surface-water supplies. The nature of such an assessment is necessarily limited by a lack of knowledge of current hydrologic conditions and the lack of agreed upon standards by which Federal, State, or local water-resource managers evaluate the effects of additional stress and future development. Current pumpage and streamflow conditions might be unknown in some areas, making the results of an evaluation of development potential highly uncertain. Future stresses also might be linked to water-management practices that have yet to be formulated, or to water-management decisions that have yet to be made. Therefore, an assessment of ground-water development potential provides insight only into one aspect of the broader question of how water-management decisions affect ground-water availability; specifically, whether existing hydrologic data document flow-system behavior adequately to allow the potential effects of future development on the flow system to be adequately evaluated and understood. Further, an assessment of ground-water development potential does not account for the suitability of existing ground-water resource management approaches or the effects of future approaches on further resource development. Such answers partly are dependent on the synthesis of results from the various Comprehensive Study components and subsequent consideration by the Federal, State, or local water managers responsible for decision-making within the basin.

The identification of areas that could be developed for ground-water supply to replace or supplement surface-water sources could not be determined from available data for Subarea 8. Because geologic controls affecting ground-water availability are highly variable, even on a local scale, regional evaluations are inherently characterized by a high degree of uncertainty. Ground-water resources probably could provide supplemental supplies during peak demand periods throughout most suburban areas of Subarea 8. In more rural areas, ground-water supplies could serve as a primary resource depending upon demands. Generally, wells need only supply about 5 gal/min for domestic users, and may not be drilled to a depth that taps the available ground-water supply at a site. Most municipal or industrial users generally require well yields of 50 to 100 gal/min or more, and wells for such supplies likely are drilled to a depth sufficient to intersect as many water-bearing zones as feasible. Municipal and industrial users also tend to drill multiple wells to obtain the required ground-water supply.

SUMMARY

Drought conditions in the 1980's have focused attention on the multiple uses of the surface- and ground-water resources in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins in Alabama, Florida, and Georgia. Federal, State, and local agencies also have proposed projects that are likely to result in additional water use and revisions of reservoir operating practices within the river basins. The existing and proposed water projects have created conflicting demands for water and emphasized the problem of allocation of the resource. This study was initiated to describe ground-water availability in the Cahaba River basin in Alabama, Subarea 8 of the ACF-ACT River basins, and to estimate the possible effects of increased ground-water use in the basin.

Subarea 8 encompasses about 6,750 square miles in the Coastal Plain physiographic province in central and southwestern Alabama. The Alabama River extends from the juncture of the Coosa and Tallapoosa Rivers near the city of Montgomery, to its juncture with the Tombigbee River, near the town of Calvert in Washington County. Subarea 8 includes the Cahaba River basin from the physiographic "Fall Line" at the city of Centreville in Bibb County to its mouth in Dallas County; and the Alabama River basin from near Montgomery to the Alabama River cutoff, about 6 miles northeast of its juncture with the Tombigbee River.

Subarea 8 is underlain by sedimentary deposits of Cretaceous, Tertiary, and Quaternary ages. Aquifers underlying Subarea 8 are, from shallowest to deepest, the alluvial aquifer, the Coastal lowlands aquifer system, the Floridan aquifer system, the Lisbon aquifer, the Nanafalia-Clayton aquifer, the Ripley aquifer, the Eutaw aquifer, and the Tuscaloosa aquifer.

The conceptual model described for this study qualitatively subdivides the ground-water flow system into local (shallow), intermediate, and regional (deep) flow regimes. Ground-water discharge to tributaries mainly is from local and intermediate flow regimes and varies seasonally. The regional flow regime probably approximates steady-state conditions and water discharges chiefly to major drains such as the Alabama River, and in upstream areas, to the Cahaba River. Ground-water discharge to major drains originates from all flow regimes. Mean-annual ground-water discharge to streams (baseflow) is considered to approximate the long-term, average recharge to ground water. The mean-annual baseflow was estimated using an automated hydrograph-separation method, and represents discharge from the local, intermediate, and regional flow regimes of the ground-water flow system. Mean-annual baseflow to the Alabama River at the confluence of the Coosa and Tallapoosa Rivers was estimated to be about 13,800 ft^3/s; about 14,600 ft^3/s total entering Subarea 8 from Subareas 5, 6, and 7; and about 20,300 ft^3/s at the mouth of the Alabama River (end of Subarea 8). Mean-annual baseflow represents about 61 percent of the mean-annual stream discharge that exits Subarea 8 at the Alabama River cutoff.

Stream discharges for selected sites on the Alabama River and tributaries were compiled for the years 1941, 1954, and 1986, during which historically significant droughts occurred throughout most of the ACF-ACT River basins. Stream discharges were assumed to be sustained entirely by baseflow during the latter periods of these droughts. Estimated baseflow near the end of the individual drought years was about 17 percent of the estimated mean-annual baseflow in Subarea 8.

The limited scope, lack of field-data collection, and the short duration of the ACF-ACT River basin study has resulted in incomplete descriptions of ground- and surface-water-flow systems, which may affect the future management of water resources in the basins. For example, the extent and continuity of local and regional flow systems and their relation to geology is largely unknown. Similarly, quantitative descriptions of stream-aquifer relations, ground-water flow across State lines, water quality, drought flows, and ground-water withdrawal and subsequent effects on the flow systems (the availability and utilization issue) are highly interpretive; therefore, the descriptions should be used accordingly.

Estimates of water use and ground-water discharge to streams are dependent on methodologies employed during data collection, computation, and analyses. Results reported herein are limited by a lack of recent data and the non-contemporaneity of all data. Analyses using limited data may not adequately describe stream-aquifer relations. Most importantly, analyses in this report describe only two hydrologic conditions—(1) mean-annual baseflow and (2) drought-flow conditions during 1941, 1954, and 1986. Analyses derived from extrapolation to other hydrologic conditions, such as much longer drought periods or increased ground-water withdrawal, should be used with caution. Special concern also should be directed to the effects of increased post-1990 withdrawal on ground-water discharge to streams in Subarea 8.

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 8. Estimated ground-water use in 1990 represented less than 1 percent of the estimated mean-annual baseflow, and about 2.4 percent of the average drought flow during the droughts of 1941, 1954, and 1986. Because ground-water use in Subareas 5 and 6 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subareas 5 and 6 in Georgia probably would have little effect on the quantity of ground water and surface water in Alabama. In addition, ground-water use in Subarea 3 in Georgia probably has no effect on the quantity of ground water and surface water in the Alabama River basin (Subarea 8) because of the lack of hydraulic connection between Subareas 3 and 8; similarly, ground-water use in Subarea 8 in Alabama probably has no effect on the quantity of ground water and surface water in Subarea 3. Although on a regional scale, only a small percentage of the mean-annual ground-water discharge is utilized, large long-term withdrawals of ground water have resulted in the formation of local depressions in the potentiometric surfaces of some of the aquifers near pumping centers. Extensive depressions have formed in the Tuscaloosa aquifer near Montgomery, Prattville, and Selma. Depressions on the potentiometric surface of the Eutaw aquifer have formed near Montgomery and Selma. A depression has formed in the potentiometric surface of the Nanafalia-Clayton aquifer in the Monroeville area.

SUGGESTIONS FOR FURTHER STUDY

This report presents a discussion of ground-water resources and the interaction of ground- and surface-water systems in the Alabama River basin, Subarea 8, of the ACF-ACT River basins. In Subarea 8, ground-water availability is addressed only from a regional perspective using historical data. Data collection was not a part of this study; therefore, lack of streamflow and ground-water data necessitated that estimation methods be used extensively to describe stream-aquifer relations. Additional data, particularly data describing surface- and ground-water conditions on a local scale, are needed to further refine and quantify the interaction of ground- and surface-water systems in the Subarea. Analyses of these data could better describe stream-aquifer relations, as well as ground-water availability and development potential in Subarea 8.

Although the overall objectives of this study were to evaluate the ground-water resources and supply, the data used to accomplish many of these study objectives were stream-discharge data. Stream-discharge data were sufficient to meet study objectives; however, such data either were not totally adequate or were not available at critical sites. Future stream-discharge data collection to support resource management should emphasize (1) continuous-record data at critical hydrologic and political boundaries for a period of years; and (2) concurrent stream-discharge measurements at critical sites during drought periods.

Continuous stream-discharge data collected over a period of years at critical locations provide the basic information essential to basinwide water-resource planning and management. Current data coverage is incomplete. For example, stream-gaging stations located at State lines and subarea boundaries would have eliminated or reduced the need to extrapolate and interpolate data from stations distant from these boundaries, and consequently, would have improved the accuracy of estimates of ground-water contributions from subarea to subarea and from State to State.

The collection of drought-flow data obviously is contingent on the occurrence of a drought; thus, collection of drought data is not routine and is not easily planned. A contingency plan to collect drought data should be in place. The plan could consider, but not be limited to, logistics, manpower needs, and the preselection of stream data-collection locations. For more rigorous planning, field reconnaissance of preselected stream sites could be conducted.

Data-base development also is critical to resource management. Data elements, such as well construction and yield; hydraulic characteristics of aquifers; water quality; and ground-water withdrawals—both areally and by aquifer—are particularly important. Seepage runs (detailed streamflow measurements of drainage systems made concurrently during baseflow conditions) can be used to identify individual ground-water flow systems and improve the understanding of stream-aquifer relations, especially in crystalline and mixed-rock terranes. Once identified, a flow system can be studied in detail to define its extent, recharge and discharge areas, movement of water, chemical quality, and the amount of water that can be withdrawn with inconsequential or minimal effects. These detailed studies might include test drilling, borehole geophysical logging, applications of surface geophysics, aquifer testing, a thorough water-withdrawal inventory, and chemical analyses of ground water to delineate the extent of the ground-water flow system and evaluate its potential as a water supply. Evaluation of several such flow systems would greatly improve the understanding of ground-water resources throughout the subarea. Because aquifer properties vary substantially on a local scale and data are sparse, field studies are needed to obtain quantitative definitions of the hydraulic interactions of aquifers and streams in Subarea 8.

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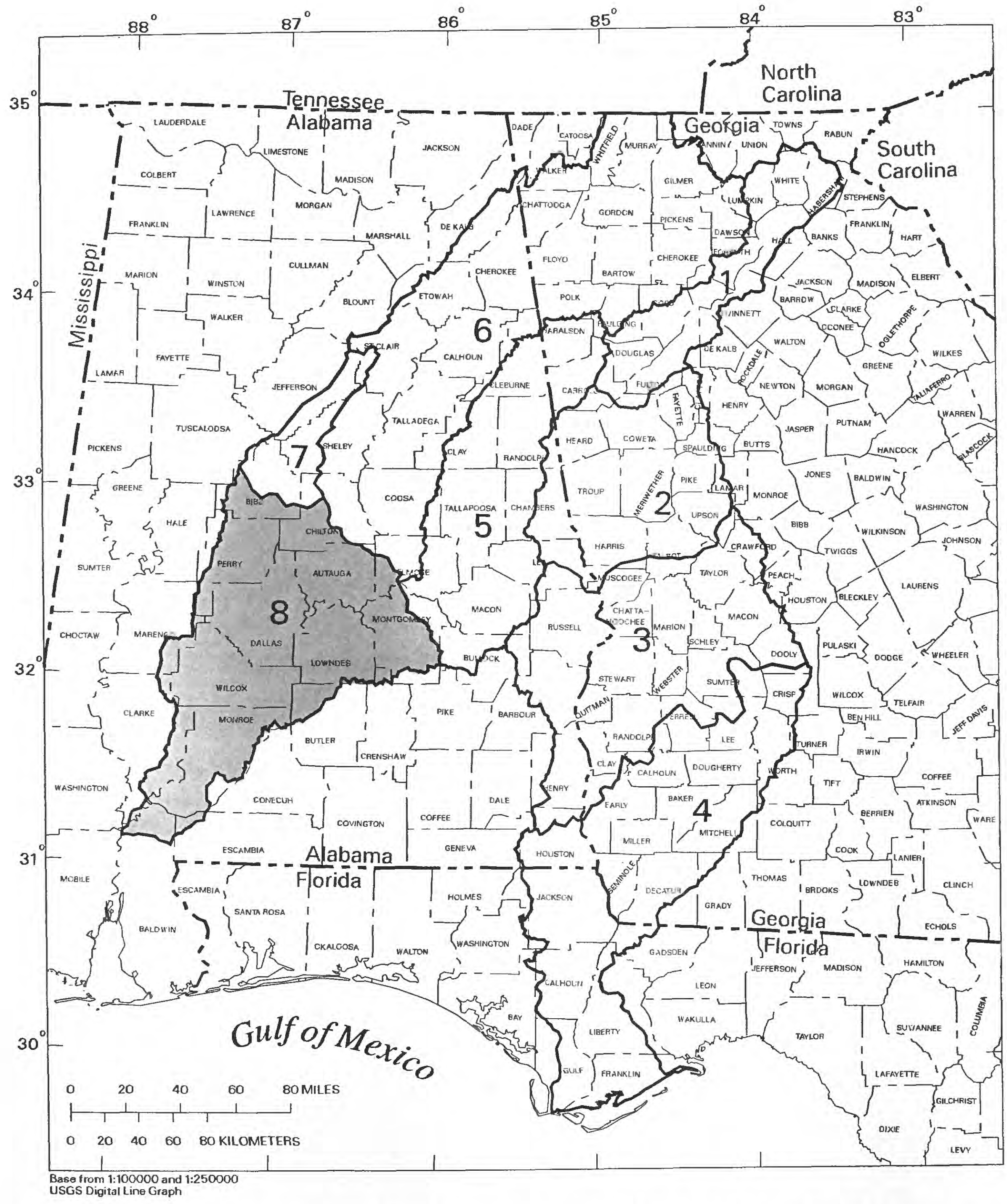

Location of subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins. Subarea described in this report is shaded.